

## U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

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DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371

5743.US

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

09/868348

INTERNATIONAL APPLICATION NO.  
PCT/GB99/04295INTERNATIONAL FILING DATE  
17 December 1999PRIORITY DATE CLAIMED  
18 December 1998

## TITLE OF INVENTION

Cyclic Adenosine Diphosphate Ribose Analogues for Modulating T Cell Activity

## APPLICANT(S) FOR DO/EO/US

B.V.L. Potter, A.H. Guse, H. Schulze-Koops, I. Berg and G.W. Mayr

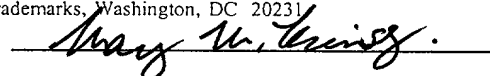
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information.

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to promptly begin national examination procedures (35 U.S.C. 371(f)).
4. ☐ The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
  - a. ☒ is attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ has been communicated by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
  - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ have been communicated by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). (5 pgs)
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

## Items 11 to 16 below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98. (and reference texts; 49 two-sided pages)
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment. (9 pgs)  
☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: International Search Report  
Written Opinion  
International Preliminary Examination Report

Certification under 37 CFR § 1.10. I hereby certify that this application is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR § 1.10 under "Express Mail" mailing number EL793307943US 15 June 2001 and is addressed to Box PCT, Commissioner of Patents and Trademarks, Washington, DC 20231.

  
Mary M. Krinsky

09/868348-001

17. <input checked="" type="checkbox"/> The following fees are submitted:				CALCULATIONS PTO USE ONLY	
<b>BASIC NATIONAL FEE ( 37 CFR 1.492 (a) (1) - (5) ) :</b> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... \$1000.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... \$860.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... \$710.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... \$690.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) ..... \$100.00 <b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>				\$ 860.00	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	- 20 =		X \$18.00	\$	
Independent claims	- 3 =		X \$80.00	\$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$270.0	\$	
<b>TOTAL OF ABOVE CALCULATIONS =</b>				\$ 860.00	
<input checked="" type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				\$ 430.00	
<b>SUBTOTAL =</b>				\$ 430.00	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
<b>TOTAL NATIONAL FEE =</b>				\$ 430.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property				+	
<b>TOTAL FEES ENCLOSED =</b>				\$ 430.00	
				Amount to be refunded:	\$
				charged:	\$

- a. ☒ A <sup>charge</sup> check in the amount of \$ 430.00 to cover the above fees is enclosed.
- b. ☐ Please charge my Deposit Account No. \_\_\_\_\_ in the amount of \$ \_\_\_\_\_ to cover the above fees.  
A duplicate copy of this sheet is enclosed.
- c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any  
overpayment to Deposit Account No. 50-0212. A duplicate copy of this sheet is enclosed.

**NOTE:** Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:



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26850  
PATENT TRADEMARK OFFICE

*Mary M. Krinsky*  
SIGNATURE

Mary M. Krinsky

NAME  
32423

REGISTRATION NUMBER

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the application of Barry V.L. Potter, *et al.*

"Cyclic Adenosine Diphosphate Ribose Analogues for Modulating T Cell Activity"

U.S. National Phase entry of PCT/GB99/04295 on June 15, 2001

**PRELIMINARY AMENDMENT**

Honorable Commissioner of Patents

Washington, D.C. 20231

Dear Sir:

For national phase entry of the above-referenced PCT application, please enter the following amendments:

Amendments

In the specification:

On page 1 before line 5, please add the following paragraph:

**CROSS-REFERENCES TO RELATED APPLICATIONS**

This application is a U.S. national phase entry of PCT/GB99/04295, filed internationally on 17 December 1999, claiming benefit of GB application number 9828071.2, filed 18 December 1998.

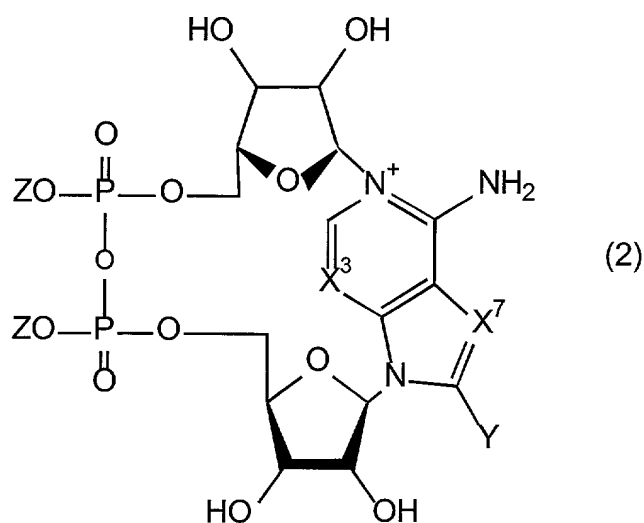
Please add the attached abstract at the end of the specification as page 39.

In the claims:

Please amend claims 1 to 5, 8 and 15 to read as follows:

09/868348-001

1. A method for modulating T cell activation *in vivo* or *ex vivo* in a mammal comprising administering to the mammal or a mammalian T cell culture an effective amount of a compound capable of antagonizing a sustained cADPR-mediated rise in intracellular  $\text{Ca}^{2+}$  levels in a T cell, said rise being in response to stimulation of the T cell receptor/CD3 complex of the T cell.
2. A method according to claim 1 wherein the compound modulates the binding of cADPR to a ryanodine receptor/ $\text{Ca}^{2+}$  channel.
3. A method according to claim 1 wherein the compound is a cADPR analogue.
4. A method according to claim 3 wherein the compound comprises an adenine component to which is individually linked two ribose moities or a derivative(s) thereof, which ribose moities are joined *via* a pyrophosphate bridging group.
5. A method according to claim 3 wherein the compound has the formula (2):



wherein:

X<sup>3</sup> is independently either CR<sup>1</sup> or N;

X<sup>7</sup> is independently either CR<sup>2</sup> or N;

Y is selected from the group consisting of halo, C<sub>1</sub> to C<sub>20</sub> hydrocarbyl, N(R<sup>3</sup>)(R<sup>4</sup>), OR<sup>5</sup>, SR<sup>6</sup> nitro and carboxyl, wherein each of R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup> and R<sup>6</sup> is independently either H or C<sub>1</sub> to C<sub>20</sub> hydrocarbyl; and

Z is independently selected from the group consisting of H, a caging group, a bio-isostere, and a pharmaceutically acceptable salt thereof.

8. A method according to claim 10 wherein the patient has a graft rejection or an autoimmune disease selected from the group consisting of thyroiditis, insulinitis, multiple sclerosis, iridocyclitis, uveitis, orchitis, hepatitis, Addison's disease, myasthenia gravis, rheumatoid arthritis and lupus erythematosus.

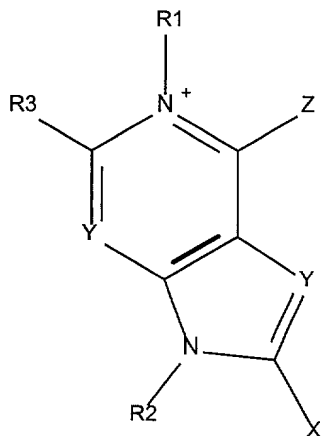
15. A compound identified by a method of claim 17.

Please cancel claims 6, 7, 9 to 14, and 16 to 18 and add the following new claims 19 to 31:

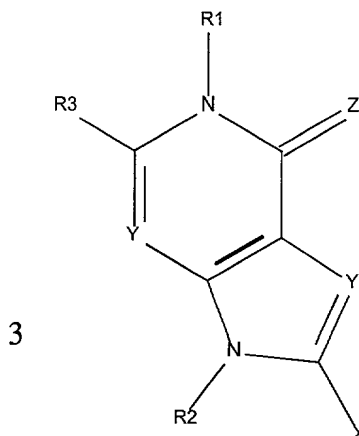
19. A method according to claim 1 wherein the compound is 7-deaza-8-Br-cADPR or 8-Br-cADPR.

20. A method according to claim 1 wherein the compounds have either formula (3) or (4):

Formula (3)



Formula (4)



wherein, for formula (3), Z is selected from the group consisting of OH, OR, SH, SR<sup>6</sup>, NH<sub>2</sub> and NHR<sup>1</sup>R<sup>2</sup> and, for formula (4), Z is selected from the group consisting of O, S, NH and NHR<sup>1</sup>; and wherein for either formula (3) or formula (4),

5 Y is either N or CH;

X is selected from the group consisting of halo, NH<sub>2</sub> or NHR<sup>1</sup>R<sup>2</sup>;

R<sub>1</sub> and R<sub>2</sub> are independently selected from the group consisting of H, C<sub>1</sub> to C<sub>20</sub> hydrocarbyl, sugar moieties and phosphate groups; and

R<sub>3</sub> is selected from the group consisting of H and C<sub>1</sub> to C<sub>20</sub> hydrocarbyl, a bio-isostere,

10 and a pharmaceutically acceptable salt thereof.

21. A method according to claim 1 which modulates the immune response in the mammal.

22. A method according to claim 1 wherein T cells are removed from a mammalian patient, treated with the compound, and then returned to the patient.

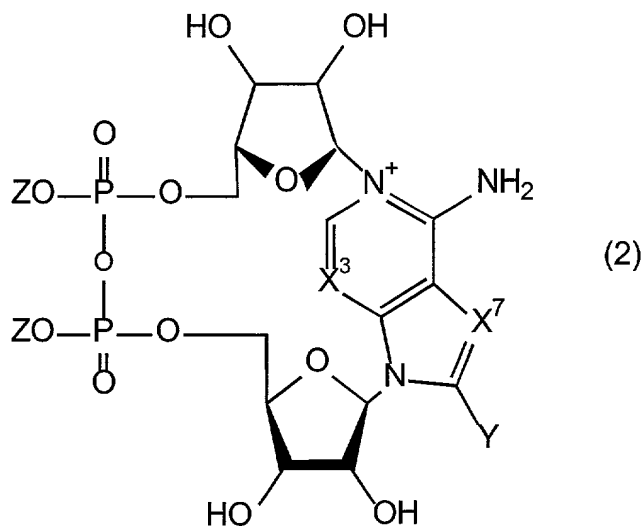
23. A method of treating a human or animal patient suffering from an immune disorder which method comprises administering to the patient an effective amount of a compound capable of antagonizing a sustained cADPR-mediated rise in intracellular Ca<sup>2+</sup> levels in a T cell, said rise being in response to stimulation of the T cell receptor/CD3 complex of the T cell, such that T cell activity is modulated.

24. A method according to claim 23 wherein the compound modulates the binding of cADPR to a ryanodine receptor/Ca<sup>2+</sup> channel.

25. A method according to claim 23 wherein the compound is a cADPR analogue.

26. A method according to claim 25 wherein the compound comprises an adenine component to which is individually linked two ribose moieties or a derivative(s) thereof, which ribose moieties are joined *via* a pyrophosphate bridging group.

27. A method according to claim 25 wherein the compound has the formula (2): formula (2):



wherein:

$X^3$  is independently either  $CR^1$  or N;

$X^7$  is independently either  $CR^2$  or N;

Y is selected from the group consisting of halo,  $C_1$  to  $C_{20}$  hydrocarbyl,  $N(R^3)(R^4)$ ,  $OR^5$ ,  $SR^6$  nitro and carboxyl, wherein each of  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$ ,  $R^5$  and  $R^6$  is independently either H or  $C_1$  to  $C_{20}$  hydrocarbyl; and

Z is independently selected from the group consisting of H, a caging group, a bio-isostere, and a pharmaceutically acceptable salt thereof.

28. A method according to claim 27 wherein the patient has rheumatoid arthritis.

29. A method for identifying a substance capable of modulating a sustained rise in  $Ca^{2+}$  entry *via* a cADPR-mediated pathway which method comprises either:

(i) contacting an ADP-ribosyl cyclase or a homologue, variant or derivative thereof, with a substance to be tested under conditions that would permit the synthesis of cADPR in the absence of the substance, and determining whether the substance affects cADPR synthesis; or

(ii) contacting a T cell, which has been stimulated *via* its T cell receptor, with a candidate substance under conditions that would permit a sustained rise in intracellular  $\text{Ca}^{2+}$  levels in the absence of the substance, and determining whether the substance inhibits a sustained rise in intracellular  $\text{Ca}^{2+}$  levels.

30. A method according to claim 29 employing the cyclase assay of alternative (i).

31. A method according to claim 29 employing the  $\text{Ca}^{2+}$  level determination of alternative (ii).

#### Remarks

This is a national phase entry of the PCT/GB99/04295 application referenced above. A "Cross-References to Related Applications" section and Abstract were added to the specification. The abstract and related application data are identical to what is presented on the front of the published version of the PCT application (WO 00/37089 dated 29 June 2000). No new matter is presented.

The pending PCT 18 claims were amended to provide a claim set that conforms to U.S. practice and eliminates multiple dependent claims to save fees. Claims 1 to 5, 8 and 15 were amended as indicated in the marked up version set out below. The rest of the claims were cancelled and replaced by new claims 19 to 31. Because the final set has 20 claims total, 3 of which are independent, no additional claim fees are due or presented herewith.

New claim 19 particularly points out specific compounds used in some embodiments described in the specification on page 11 at lines 6 to 7. New claim 20 particularly points out a couple of groups of compounds used in embodiments set out in the specification on page 11 at lines 10 to 22. New claim 8 directed to immune response modulation in mammals is supported in the specification on page 5 at lines 21 to 22.



New claim 22 directed to *ex vivo* therapy is supported in the specification on page 16 at lines 20 to 21. New claim 23 is a rewritten version of originally presented claim 1 supported in the specification on page 16 at lines 16 to 24. Claims 24 to 26 track the language of originally presented claims 2 to 4. New claim 27 combines the limitations of originally presented claims 11 to 13. New claim 30 particularly points out an embodiment set out in former claim 11, and new claim 31 is directed to the embodiment originally presented in claim 13. No new matter is presented.

If the undersigned can assist in the prosecution of this application in any way, please call at the number below.

Respectfully submitted,



Mary M. Krinsky, Reg. 32423

79 Trumbull St., New Haven, CT 06511

203-773-9544

**Marked-Up Copy of Amendments Required by 37 C.F.R. 1.121**

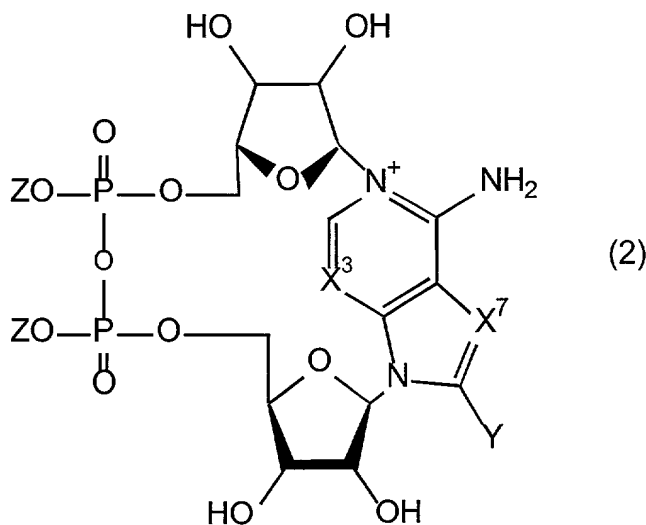
1 (Amended). [Use of] A method for modulating T cell activation *in vivo* or *ex vivo* in a mammal comprising administering to the mammal or a mammalian T cell culture an effective amount of a compound capable of [antagonising] antagonizing a sustained cADPR-mediated rise in intracellular  $\text{Ca}^{2+}$  levels in a T cell, said rise being in response to stimulation of the T cell receptor/CD3 complex of the T cell[, in the manufacture of a medicament for use in modulating T cell activity].

2 (Amended). [Use] A method according to claim 1 wherein the compound modulates the binding of cADPR to a ryanodine receptor/ $\text{Ca}^{2+}$  channel.

3 (Amended). [Use] A method according to claim 1 [or claim 2] wherein the compound is a cADPR analogue.

4 (Amended). [Use] A method according to claim 3 wherein the compound comprises an adenine component to which is individually linked two ribose moieties or a derivative(s) thereof, which ribose moieties are joined *via* a pyrophosphate bridging group.

5 (Amended). [Use] A method according to claim 3 wherein the compound has the formula (2):



wherein:

$X^3$  is independently [selected from] either  $CR^1$  [and] or N;

$X^7$  is independently [selected from] either  $CR^2$  [and] or N;

Y is selected from the group consisting of halo,  $C_1$  to  $C_{20}$  hydrocarbyl,  $N(R^3)(R^4)$ ,  $OR^5$ ,  $SR^6$  nitro and carboxyl;

each of  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$ ,  $R^5$  and  $R^6$  is independently [selected from] either H [and] or  $C_1$  to  $C_{20}$  hydrocarbyl; and

Z is independently selected selected from the group consisting of H, [and] a caging

8 (Amended). [Use] A method according to claim [7] 10 wherein the patient has a graft rejection or an autoimmune disease is selected from thyroiditis, insulinitis, multiple sclerosis, iridocyclitis, uveitis, orchitis, hepatitis, Addison's disease, myasthenia gravis, rheumatoid arthritis and lupus erythematosus.

15. A compound identified by the method of claim [11, 12 or 13] 17.

# ABSTRACT OF THE DISCLOSURE

Compounds capable of antagonizing a sustained cADPR-mediated rise in intracellular  $\text{Ca}^{2+}$  levels in a T cell, said rise being in response to stimulation of the T cell receptor/CD3 complex of the T cell, methods for identifying the same and their use in modulating T cell activity are described.

096243-061394

THERAPEUTICS

CYCLIC ADENOSINE DIPHOSPHATE RIBOSE ANALOGUES FOR MODULATING T CELL ACTIVITY

5 The present invention relates to therapeutics. In particular, the present invention relates to the modulation of T cell responses using compounds capable of regulating activation of T cells *via* a cyclic ADP ribose mediated pathway. The invention also relates to treating autoimmune disease and graft rejection using such compounds and methods for identifying such compounds.

10

Background to the Invention

Adaptive or specific immune responses are normally stimulated when an individual is exposed to a foreign antigen. Specific immunity is mediated by lymphocytes, e.g. B and T  
15 lymphocytes. During an immune response, recognition of an antigen leads to activation of lymphocytes that specifically recognise that particular antigen. The lymphocytes proliferate and differentiate into specialised effector cells. The immune response culminates in the development of mechanisms that ultimately eliminate the antigen.

20 Adaptive immune responses are critical components of host defence during protection against foreign antigens, such as infectious organisms or toxins. However, specific immune responses are also sometimes elicited by antigens not associated with infectious agents, and this may cause serious disease. For example, one of the most remarkable properties of specific immunity is the ability to distinguish between self antigens and  
25 foreign antigens. Thus, the lymphocytes in each individual are able to recognise and respond to numerous foreign antigens but are normally unresponsive to potentially antigenic substances present in the individual itself. Unresponsiveness to self antigens is an acquired process that has to be learned by the individual's lymphocytes and has to be maintained throughout life.

30

Abnormalities in the induction or maintenance of self-tolerance lead to immune responses against self antigens, and debilitating diseases that are commonly called autoimmune

09/868348 PCT/GB99/04295

diseases. The spectrum of autoimmune disorders ranges from organ specific diseases (such as thyroiditis, insulinitis, multiple sclerosis, iridocyclitis, uveitis, orchitis, hepatitis, Addison's disease, myasthenia gravis) to systemic illnesses such as rheumatoid arthritis or lupus erythematosus.

5

Another example in which specific immunity against antigens that are not associated with infections causes severe medical problems are rejections of transplanted allografts. In fact, adaptive immune responses to grafted tissues are the major impediment to successful transplantation in most cases.

10

It is not known what causes the breakdown of tolerance and the initiation of an autoimmune response. However, the mechanisms of tissue destruction in autoimmune diseases and in allograft rejection are essentially the same as those operating in protective immunity. It is generally believed that both autoimmune reactions and allograft rejections are initiated and perpetuated by a response involving T cells. Thus, in the absence of a specific therapy for any of the autoimmune diseases or for allograft rejection, many therapeutic strategies currently employed aim at down modulating the activity of the immune system, in particular by reducing or preventing the activation of T cells.

15

20 Recently, monoclonal antibodies to T cell surface antigens, that inhibit T cell activation, or substances that interfere with intracellular T cell activation pathways, such as Cyclosporin A or FK506, have been introduced for the treatment of both allograft rejection and several autoimmune diseases. However, current approaches for the treatment of undesirable T cell activation have been associated with a number of side effects related to general immunosuppression and therefore cannot be considered to be optimal therapy.

25

Stimulation of T-lymphocytes *via* the T cell receptor/CD3 complex (TCR/CD3) is a critical step in T cell activation and subsequent clonal expansion. Previous studies have shown that activation of the TCR/CD3-complex involves the elevation of the free cytosolic  $\text{Ca}^{2+}$  concentration ( $[\text{Ca}^{2+}]_i$ ) by at least two mechanisms, a rapid elevation caused by  $\text{Ca}^{2+}$  release from intracellular stores mediated by inositol (1,4,5) trisphosphate ( $\text{Ins}(1,4,5)\text{P}_3$ ), and a prolonged elevation that is completely dependent on the influx of extracellular

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calcium (reviewed in Guse, 1998).  $\text{Ins}(1,4,5)\text{P}_3$  appears to play an essential role in  $\text{Ca}^{2+}$  signalling stimulated *via* the TCR/CD3-complex, since expression of an anti-sense construct directed against the type 1  $\text{Ins}(1,4,5)\text{P}_3$  receptor in Jurkat T cells resulted in complete abolition of CD3-mediated  $\text{Ca}^{2+}$  signalling (Jayaraman *et al*, 1995).

5 The exact mechanism of  $\text{Ca}^{2+}$  entry in T cells is still unknown. However, (i) the electrophysiological properties of the  $\text{Ca}^{2+}$  channels involved, (ii) the absence of  $\text{Ca}^{2+}$  entry induced by either TCR/CD3 stimulation or  $\text{Ca}^{2+}$  store depletion in T cells from an immunodeficient patient, and (iii) the observation that mutants in thapsigargin-stimulated  
10  $\text{Ca}^{2+}$  entry also were defective in TCR/CD3-mediated  $\text{Ca}^{2+}$  entry argue for the capacitative model in the sustained process of  $\text{Ca}^{2+}$  entry. Although the exact mechanism of  $\text{Ca}^{2+}$  entry is still unclear, it is of fundamental importance for a functional immune response since T cells absolutely require the sustained  $\text{Ca}^{2+}$  signal for clonal expansion. Furthermore, an improved understanding of the signalling pathways involved in T cell activation may be of  
15 assistance in developing strategies to suppress inappropriate T cell activity.

#### Summary of the Invention

We have now shown that the potent  $\text{Ca}^{2+}$  mobilising compound cyclic ADP-ribose  
20 (cADPR), which is found in a variety of eukaryotic cells, is essentially required for sustained  $\text{Ca}^{2+}$  signalling mediated *via* stimulation of the T cell receptor/CD3 (TCR/CD3) complex. Thus we have shown for the first time that cADPR has a role as a second messenger in T cell activation *via* the TCR/CD3 complex.

25 Using HPLC analysis (da Silva *et al*, 1998), we have demonstrated that stimulation of the TCR/CD3 complex resulted in activation of a soluble ADP-ribosyl cyclase and a sustained elevation of the intracellular level of cADPR. A causal relationship between elevated cADPR, sustained  $\text{Ca}^{2+}$  signalling and activation of T cells was revealed by inhibition of TCR/CD3-stimulated  $\text{Ca}^{2+}$  signalling, cell proliferation and expression of early and late  
30 activation markers, CD25 and HLA-DR, using the membrane-permeant antagonist 7-deaza-8-Br-cADPR (WO-A-98/43992). Expression of the molecular target for cADPR in T cells, the type 3 ryanodine receptor/ $\text{Ca}^{2+}$  channel, was demonstrated both by RT-PCR

and immunoprecipitation/western blotting. Increased cADPR significantly and specifically stimulated the apparent association of [<sup>3</sup>H] ryanodine indicating a direct modulatory effect on channel opening. In summary, we have shown the presence, causal relation and biological significance of the major constituents of the cADPR/Ca<sup>2+</sup> signalling pathway in human T cells.

These findings may have important implications for the design of compounds capable of modulating T cell activity since regulation of this cADPR/Ca<sup>2+</sup> signalling pathway may provide an important means of controlling T cell responses in a variety of T cell mediated immune disorders.

Further, we have also shown that a cADPR antagonist, 7-deaza-8-Br-cADPR, is capable of reducing immune responses in a murine antigen-induced arthritis model. Thus we have demonstrated that a compound that has an effect on the cADPR/Ca<sup>2+</sup> signalling pathway can inhibit immune responses *in vivo*.

Accordingly the present invention provides a compound for use in modulating T cell activity which compound is capable of antagonising a sustained cADPR-mediated rise in intracellular Ca<sup>2+</sup> levels in a T cell, said rise being in response to stimulation of the T cell receptor/CD3 complex of the T cell.

Compounds of the invention may be used in treating (i) an autoimmune disease such as an autoimmune disease selected from thyroiditis, insulinitis, multiple sclerosis, iridocyclitis, uveitis, orchitis, hepatitis, Addison's disease, myasthenia gravis, rheumatoid arthritis and lupus erythematosus or (ii) allograft rejection.

The elucidation of a novel cADPR-mediated T cell activation pathway will also enable the identification of substances that modulate T cell activation *via* this pathway. Such substances may be used to modulate T cell activity, for example to suppress inappropriate T cell activity in autoimmune reactions or in response to tissue transplantation as an alternative to existing general immunosuppressants such as Cyclosporin A and FK506.

Accordingly, the present invention provides a method for identifying a substance capable of modulating a sustained rise in  $\text{Ca}^{2+}$  entry *via* a cADPR-mediated pathway which method comprises:

- 5 (i) contacting a T cell, which has been stimulated *via* its T cell receptor, with a candidate substance under conditions that would permit a sustained rise in intracellular  $\text{Ca}^{2+}$  levels in the absence of the substance; and
- (ii) determining whether the substance inhibits a sustained rise in intracellular  $\text{Ca}^{2+}$  levels.

10 The present invention further provides a method for identifying a substance capable of modulating a sustained rise in  $\text{Ca}^{2+}$  entry *via* a cADPR-mediated pathway which method comprises:

- (i) contacting an ADP-ribosyl cyclase or a homologue, variant or derivative thereof, with a substance to be tested under conditions that would permit the synthesis of cADPR in  
15 the absence of the substance; and
- (ii) determining whether the substance affects cADPR synthesis.

In one embodiment, the substance inhibits cADPR synthesis, for example reduces or abolishes cADPR synthesis. In another embodiment, the substance modulates, for  
20 example inhibits, binding of endogenous cADPR to its receptor binding site.

A compound identified by the methods of the invention may be used in modulating the immune response of a mammal. Thus, for example, in another aspect of the present invention, a compound identified by a method of the invention is provided for use in  
25 treating (i) an autoimmune disease, such as thyroiditis, insulinitis, multiple sclerosis, iridocyclitis, uveitis, orchitis, hepatitis, Addison's disease, myasthenia gravis, rheumatoid arthritis and lupus erythematosus or (ii) allograft rejection.

The present invention also provides a pharmaceutical composition (which term also  
30 includes a veterinary formulation) comprising a compound of the present invention, or a pharmaceutically acceptable salt thereof, or a pharmaceutically acceptable solvate of either entity, together with a pharmaceutically acceptable diluent, excipient or carrier.



The invention further provides a compound of the present invention, or a pharmaceutically acceptable salt thereof, or a pharmaceutically acceptable solvate of either entity, or a pharmaceutical composition containing any of the foregoing, for use as a human or animal medicament.

#### Detailed Description of the Invention

##### **A. Compounds capable of inhibiting cADPR mediated sustained $\text{Ca}^{2+}$ signalling in T cells.**

Compounds suitable for use in the present invention are capable of inhibiting cADPR-mediated sustained  $\text{Ca}^{2+}$  signalling in T cells. Preferably, inhibition is specific for the second phase sustained influx of  $\text{Ca}^{2+}$  resulting from stimulation of the T cell receptor/CD3 complex. In particular, it is preferred that a compound for use in the present invention does not substantially inhibit other pathways involved in the release of  $\text{Ca}^{2+}$  from intracellular stores, for example  $\text{Ins}(1,4,5)\text{P}_3$  mediated release of  $\text{Ca}^{2+}$  from intracellular stores. Alternatively, although a compound suitable for use in the present invention may affect to some degree other pathways involved in the release of  $\text{Ca}^{2+}$  from intracellular stores, it is preferred that the compounds preferentially inhibit cADPR-mediated sustained  $\text{Ca}^{2+}$  entry into T cells. For example, a preferred compound will inhibit the cADPR pathway at least two-fold, preferably at least 5 or 10-fold more than other pathways involved in  $\text{Ca}^{2+}$  signalling resulting from TCR/CD3 stimulation.

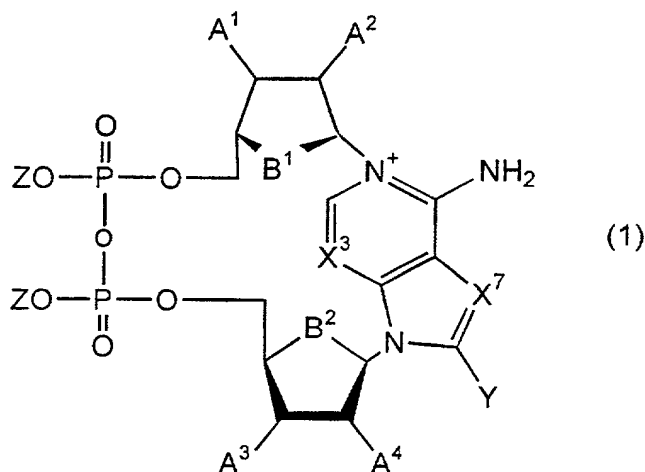
The two phases of  $\text{Ca}^{2+}$  signalling in T cells have been characterised previously and thus it is well within the capabilities of the skilled person to determine using routine methods whether a compound has an affect on the first phase of  $\text{Ca}^{2+}$  release or the second, sustained phase of  $\text{Ca}^{2+}$  signalling. An example of such a method is ratiometric  $\text{Ca}^{2+}$  imaging.

A compound for use in the present invention may act at a number of places in the cADPR  $\text{Ca}^{2+}$  signalling pathway. It may affect signalling between the activated TCR/CD3 complex

and ADP-ribosyl cyclase. It may affect activation of a cADPR-metabolising enzyme, for example ADP-ribosyl cyclase (such as covalent modification by an upstream effector protein, for example a kinase), or enzymatic activity of the cADPR-metabolising enzyme (such as a competitive inhibitor having a high binding affinity for the active site of the enzyme or a non-competitive inhibitor which binds a distal site resulting in a conformational change). Alternative, it may affect downstream effects of cADPR (such as channel opening of the ryanodine/ $\text{Ca}^{2+}$ -channel, which is detectable as modulation of ryanodine binding to ryanodine receptors). In particular preferred compounds such as cADPR analogues may act to inhibit binding of cADPR to its binding site on the ryanodine receptor/ $\text{Ca}^{2+}$  channel. Suitable assays for identifying compounds for use in the present invention are described below in section B.

One particularly preferred class of compounds for use in the present invention are cADPR analogues, for example a compound comprising an adenine component to which is individually linked two ribose moieties or a derivative(s) thereof, which ribose moieties are joined *via* a pyrophosphate bridging group or a more hydrophobic isostere (i.e. an organic linker of similar size but less polar). Preferably, the ribose moieties are joined to the adenine component at the 1 and 9 positions. Preferably the ribose moieties are joined to the pyrophosphate bridging group or isostere thereof at the 5' position of the ribose rings.

Particular compounds include compounds of formula (1):



wherein:

$A^1$ ,  $A^2$ ,  $A^3$  and  $A^4$  are independently selected from OH, H, F,  $NH_2$ ,  $N_3$  and O-hydrocarbyl;

$B^1$  and  $B^2$  are independently selected from O, S, CHF,  $CF_2$ , SO, NR and  $CH_2$

$X^3$  is independently selected from  $CR^1$  and N;

5  $X^7$  is independently selected from  $CR^2$  and N;

Y is halo,  $C_1$  to  $C_{20}$  hydrocarbyl,  $N(R^3)(R^4)$ ,  $OR^5$ ,  $SR^6$  nitro and carboxyl;

each of R,  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$ ,  $R^5$  and  $R^6$  is independently selected from H and  $C_1$  to  $C_{20}$  hydrocarbyl; and

10 Z is independently selected from H and a group that increases the membrane permeability of the compound;  
or a bio-isostere; or a pharmaceutically acceptable salt thereof.

15  $A^1$ ,  $A^2$ ,  $A^3$  and  $A^4$  are preferably OH or O-acyl.  $B^1$  and  $B^2$  are preferably O. Preferably  $X^7$  is CH and  $X^3$  is N. Y is preferably halo, i.e. chloro, fluoro, iodo (either a natural or a radioisotope such as  $^{125}I$ ) or bromo, particularly bromo. Alternatively Y may be amino. Preferably each of R,  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$ ,  $R^5$  and  $R^6$  is independently selected from H and  $C_1$  to  $C_{10}$  hydrocarbyl, more preferably H and  $C_1$  to  $C_5$  hydrocarbyl.

20 The term "hydrocarbyl group" means a group comprising at least C and H and may optionally comprise one or more other suitable substituents. Examples of such substituents may include halo-, alkoxy-, nitro-, an alkyl group, a cyclic group etc. In addition to the possibility of the substituents being a cyclic group, a combination of substituents may form a cyclic group. If the hydrocarbyl group comprises more than one C then those carbons need not necessarily be linked to each other. For example, at least two of the carbons may  
25 be linked *via* a suitable element or group (e.g. carbonyl). Thus, the hydrocarbyl group may contain hetero atoms. Suitable hetero atoms will be apparent to those skilled in the art and include, for instance, sulphur, nitrogen and oxygen.

30 Preferably, the hydrocarbyl group is any one or more of an alkyl group, an alkylene group, an alkenylene group, an alkenyl group, an alkynylene group, an acyl group or an aryl group, including combinations thereof (e.g. an arylalkyl group) - which groups may optionally

contain one or more heteroatoms or groups, and may further comprise substituents on the chain or rings.

5 In one preferred embodiment of the present invention, the hydrocarbonyl group is a hydrocarbon group.

Here the term "hydrocarbon" means any one of an alkyl group, an alkenyl group, an alkynyl group, which groups may be linear, branched or cyclic, or an aryl group, or combinations thereof (e.g. an arylalkyl group). The term hydrocarbon also includes those  
10 groups but wherein they have been optionally substituted. If the hydrocarbon is a branched structure having substituent(s) thereon, then the substitution may be on either the hydrocarbon backbone or on the branch; alternatively the substitutions may be on the hydrocarbon backbone and on the branch. Preferably, at least one of  $R^{1-6}$  is H or  $C_1$  to  $C_4$  alkyl.

15 Compounds of the present invention may contain one or more asymmetric carbon atoms and/or one or more non-aromatic carbon-carbon double bonds and may therefore exist in two or more stereoisomeric forms. Thus, the present invention also provides individual stereoisomers of the compounds of the formula (1), as well as mixtures thereof, including  
20 compositions comprising the same. Separation of diastereoisomers or *cis* and *trans* isomers may be achieved by conventional techniques, e.g. by fractional crystallisation, chromatography or HPLC of a stereoisomeric mixture of a compound of the formula (I) or a suitable salt or derivative thereof. An individual enantiomer of a compound of the formula (1) may also be prepared from a corresponding optically pure intermediate or by  
25 resolution, such as by HPLC of a racemate using a suitable chiral support or by fractional crystallisation of the diastereoisomeric salts formed by reaction of a racemate with a suitable optically active acid or base.

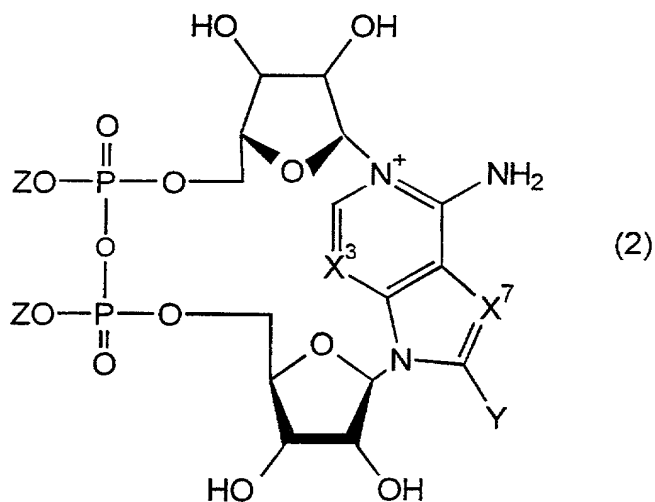
30 Either both Z groups represent hydrogen atoms (or negative charges) as in a conventional diphosphate system or one Z group may be a group that protects the phosphorous to which it is attached and preferably increases the membrane permeability of the compound (i.e. a hydrophobic group, for example O-acyl groups such as acetoxymethyl), but which

preferably is subsequently removed upon entry into the cell. In a similar manner, one Z group may be a "caging" group e.g. 1-(o-nitrophenyl)ethyl, whereby the compound of the invention is a caged analogue adapted to be converted into an active compound *in situ* e.g. by light irradiation. The chemistry of such caged analogues is well known (see Aarhus *et al.*, 1995; McCray and Trentham, 1989) and such compounds can be prepared by standard methods. The term "caging group" is used in its normal sense - namely a stable group which is labile on irradiation.

The term "bio-isostere" is used in its normal sense - namely a similar (but not the same) or a different chemical structure and having the same biological functional effect.

Preferably the cADPR analogues of formula (1) are substantially non-hydrolysable (the Z group excepted wherein it is other than H).

In a particularly preferred embodiment, a compound for use in the present invention has the formula (2):



wherein:

$X^3$  is independently selected from  $CR^1$  and N;

$X^7$  is independently selected from  $CR^2$  and N;

Y is halo,  $C_1$  to  $C_{20}$  hydrocarbyl,  $N(R^3)(R^4)$ ,  $OR^5$ ,  $SR^6$  nitro and carboxyl;

each of  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$ ,  $R^5$  and  $R^6$  is independently selected from H and  $C_1$  to  $C_{20}$  hydrocarbyl; and

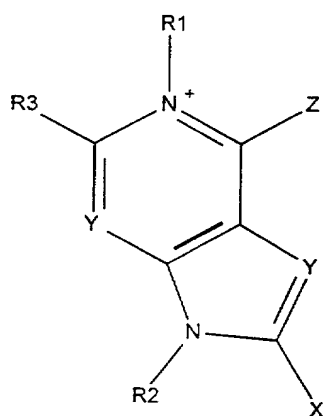
Z is independently selected from H and a group that increases the membrane permeability of the compound;

5 or a bio-isostere; or a pharmaceutically acceptable salt thereof.

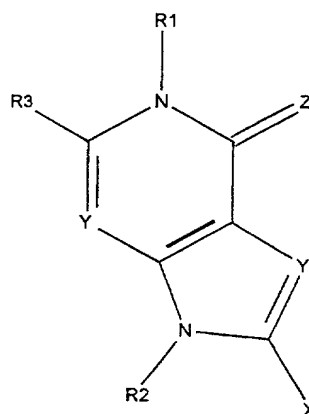
Compounds of formula (2) may be prepared as described in PCT/GB98/00921. Particularly preferred compounds are 7-deaza-8-Br-cADPR and 8-Br-cADPR.

10 Other preferred compounds include compounds of formula (3) or (4)

Formula (3)



Formula (4)



Where for formula (3), Z is selected from OH, OR, SH,  $SR^6$ ,  $NH_2$  and  $NHR^1R^2$  and for  
15 formula (4), Z is selected from O, S, NH and  $NHR^1$ ; and

wherein for either formula (3) or formula (4),

Y is selected from N or CH;

X is halo,  $NH_2$  or  $NHR^1R^2$ ;

$R_1$  and  $R_2$  are independently selected from H,  $C_1$  to  $C_{20}$  hydrocarbyl, sugar moieties and  
20 phosphate groups; and

$R_3$  can be any group but is preferably selected from H and  $C_1$  to  $C_{20}$  hydrocarbyl;  
or a bio-isostere; or a pharmaceutically acceptable salt thereof.

The terms "bio-isostere", "halo", "R<sup>1</sup>", "R<sup>2</sup>", "R<sup>6</sup>" and "C<sub>1</sub> to C<sub>20</sub> hydrocarbyl" are defined above.

R<sub>1</sub> and R<sub>2</sub> may be joined *via* a cyclic linker group.

5

Preferably each of R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, R<sup>1</sup>, R<sup>2</sup> and R<sup>6</sup> is independently selected from H and C<sub>1</sub> to C<sub>10</sub> hydrocarbyl, more preferably H and C<sub>1</sub> to C<sub>5</sub> hydrocarbyl.

**B. Assays for identifying compounds capable of inhibiting cADPR-mediated sustained Ca<sup>2+</sup> signalling in T cells.**

10

A substance which affects the cADPR pathway may do so in several ways as discussed above. For example, it may disrupt an interaction between two components of the pathway. In particular, it preferably disrupts the binding of cADPR to its binding site on the ryanodine receptor/Ca<sup>2+</sup> channel. It may directly disrupt the binding of the two components by, for example, binding to one component and masking or altering the site of interaction with the other component. Candidate substances of this type may conveniently be screened by *in vitro* binding assays. Examples of candidate substances include non-functional homologues of either of the two components as well as antibodies which recognize either of the two components.

15

20

A substance which can bind directly to either of the two components may also inhibit an interaction between the two components by altering their subcellular localization thus preventing the two components from coming into contact within the cell. This can be tested *in vivo* using, for example the *in vivo* assays described below. The term '*in vivo*' is intended to encompass experiments with cells in culture as well as experiments with intact multicellular organisms.

25

Alternatively, instead of preventing the association of the components directly, the substance may suppress or enhance the biologically available amount of one or both of the components. This may be by inhibiting expression of the component, for example at the level of transcription, transcript stability, translation or post-translational stability. An

30

example of such a substance would be antisense RNA which suppresses the amount of ADP-ribosyl cyclase mRNA translated into protein or antisense RNA which suppresses the amount of type 3 ryanodine receptor mRNA translated into protein.

- 5 Suitable candidate substances also include antibody products (for example, monoclonal and polyclonal antibodies, single chain antibodies, chimeric antibodies and CDR-grafted antibodies) which are specific for either of the two components. Furthermore, combinatorial libraries, peptide and peptide mimetics, defined chemical entities, oligonucleotides, and natural product libraries may be screened for activity as inhibitors of  
10 an interaction between the two components. Other candidate substances include analogues of substrates or products of the cADPR pathway, such as cADPR analogues or NAD analogues.

- The candidate substances may be used in an initial screen in batches of, for example 10  
15 substances per reaction, and the substances of those batches which show inhibition tested individually. Candidate substances which show activity in *in vitro* screens such as those described below may then be tested in *in vivo* systems.

- In vitro* assays typically test for substances capable of affecting the interaction between  
20 particular components of the signalling pathway (see above) or the activity of a particular component, such as an enzyme. For example, one assay may involve testing candidate substances for the ability to inhibit synthesis of cADPR by an ADP-ribosyl cyclase. This may be performed by (i) contacting an ADP-ribosyl cyclase with a candidate substance under conditions that would allow the synthesis of cADPR in the absence of the candidate  
25 substance and (ii) determining if the candidate substance inhibits cADPR synthesis.

- A suitable source of ADP-ribosyl cyclase may be, for example, purified recombinant protein or a crude preparation of T cell extracts. Levels of cADPR may be measured using a combined two-step HPLC method as described in da Silva *et al.* (1998) which has a  
30 detection sensitivity for cADPR of about 10 pmol. Typically, cADPR is extracted from cells using perchloric acid. Suitable exogenous substrates for the reaction are  $\text{NAD}^+$  or a fluorescent analogue (e.g. 1,  $\text{N}^6$ -etheno-NAD) and may be added at concentrations of about



100  $\mu$ M to 1 mM. Alternatively, in the case of cell extracts, endogenous substrates may be sufficient.

Other *in vitro* assays may include assays for identifying substances capable of disrupting  
5 ryanodine binding to ryanodine receptors. For example, membrane preparations may be obtained from T cells as described in the Examples and the kinetics of [ $^3$ H]ryanodine binding to the membrane preparation assessed in the absence or presence of a candidate substance.

10 A further *in vitro* assay may be used to identify substances that disrupt the binding of cADPR to its receptor on the ryanodine receptor/ $\text{Ca}^{2+}$  channel. Again, membrane preparations may be obtained from T cells as described in the Examples and the binding of cADPR to the membrane preparation assessed in the absence or presence of a candidate substance. Alternatively, purified or recombinant ryanodine receptor/ $\text{Ca}^{2+}$  channel may be  
15 used instead of membrane preparations (the cloning of a part of the type 3 ryanodine receptor/ $\text{Ca}^{2+}$  channel is described in the examples).

*In vitro* assays will generally be used as a preliminary step prior to *in vivo* testing since it is only in the context of an intact TCR/CD3  $\text{Ca}^{2+}$  signalling pathway that the modulatory  
20 effects of a candidate substance may be completely assessed. *In vivo* assays will typically use either T cell lines, preferably human T cell lines, or T cells obtained from animal tissues, especially human tissues. Generally, T cells will be stimulated *via* the TCR/CD3 complex using standard methods such as receptor cross-linking using antibodies that recognise the receptor complex. They may also be stimulated using superantigens or  
25 antigen presenting cells, such as dendritic cells.

A suitable assay method comprises stimulating a T cell *via* its TCR/CD3 receptor in the presence or absence of a candidate substance. The  $\text{Ca}^{2+}$  response is measured (for example using ratiometric  $\text{Ca}^{2+}$  imaging) and compared. An effect on sustained  $\text{Ca}^{2+}$  entry is  
30 indicative of a substance capable of modulating T cell activity *via* a cADPR pathway. However, to discount the possibility that the effect may be due to modulation of  $\text{Ca}^{2+}$  release *via* an  $\text{Ins}(1,4,5)\text{P}_3$  pathway, it is preferred that the first rapid phase of  $\text{Ca}^{2+}$  is

substantially unaffected. The sustained phase of  $\text{Ca}^{2+}$  entry is typically taken to be from approximately 15 minutes after stimulation of the T cell.

5 T cells may be contacted with a candidate substance before, concomitant with, or after stimulation of the TCR/CD3 complex. The concentration of candidate substance administered to the cell will vary but is typically from 0.1 to 100  $\mu\text{M}$ , more preferably from 1 to 100  $\mu\text{M}$  or 10 to 100  $\mu\text{M}$ .

10 **C. Assays for testing the physiological affects of substances capable of modulating a cADPR pathway.**

Since the intention of identifying substances that affect the cADPR pathway is to use them to modulate T cell activity, further assays may comprise administering a substance capable of modulating the activity of the pathway to a T cell, or a candidate substance, and  
15 determining the effect on the cell. For example, compounds for use in the present invention are preferably capable of inhibiting or reducing the sustained rise in  $\text{Ca}^{2+}$  levels following stimulation of the cell *via* the TCR/CD3 complex. Such an affect may include inhibition of cell proliferation in response to, for example, stimulation by an antigen presenting cell such as a dendritic cell. Thus one suitable assay comprises incubating a T  
20 cell with an antigen presenting cell in the presence or absence of a candidate substance and determining whether T cell proliferation is reduced in the presence of the substance compared in the absence of the substance.

Another suitable assay involves activating a T cell with a mitogen in the presence and  
25 absence of a candidate substance and determining whether T cell proliferation is reduced in the presence of the substance compared in the absence of the substance. Examples of suitable mitogens include monoclonal antibodies to CD3 or the TCR, phorbol 12-myristate 13-acetate, ionomycin, concanavalin A, phytohemagglutinin, superantigens and antibodies to CD2, CD3 or the T cell receptor.

30

T cell activation/proliferation may be measured using a variety of techniques, for example by measuring levels of secreted cytokines such as IL-2 in the culture medium or by

flowcytometric analysis of T cell surface markers indicative for activation (such as CD69, CD30, CD25 and HLA-DR).

- 5 A preferred substance is capable of reducing T cell proliferation by at least 50%, more preferably at least 60, 70, 80 or 90% (for example with respect to numbers of cells expressing a cell surface marker, cytokine levels in the medium and/or numbers of cells present).

- 10 Another suitable *in vivo* assay, which is described in example 5, is a murine antigen induced arthritis model. Test compounds are typically administered to mice preimmunised with methylated bovine serum albumin (mBSA) in complete Freund's adjuvant, with the experimental arthritis being induced by injection of mBSA into the right knee joint. Compounds are typically administered by intraperitoneal injection.

15 **D. Therapeutic Uses**

- 20 Compounds capable of affecting a cADPR mediated rise in  $\text{Ca}^{2+}$  levels in T cells may be used in methods of therapy, for example in treating immune disorders such as autoimmune diseases or graft rejection such as allograft rejection. In particular such compounds may be used to inhibit T cell responses *in vivo*. Alternatively, T cells may be removed from a patient, treated and then returned to the patient (*ex vivo* therapy).

- 25 Examples of disorders that may be treated include a group commonly called autoimmune diseases. The spectrum of autoimmune disorders ranges from organ specific diseases (such as thyroiditis, insulinitis, multiple sclerosis, iridocyclitis, uveitis, orchitis, hepatitis, Addison's disease, myasthenia gravis) to systemic illnesses such as rheumatoid arthritis or lupus erythematosus. Other disorders include immune hyperreactivity, such as allergic reactions.

- 30 In more detail: Organ-specific autoimmune diseases include multiple sclerosis, insulin dependent diabetes mellitus, several forms of anemia (aplastic, hemolytic), autoimmune hepatitis, thyroiditis, insulinitis, iridocyclitis, skleritis, uveitis, orchitis, myasthenia gravis,

idiopathic thrombocytopenic purpura, inflammatory bowel diseases (Crohn's disease, ulcerative colitis).

Systemic autoimmune diseases include: rheumatoid arthritis, juvenile arthritis, scleroderma and systemic sclerosis, sjogren's syndrom, undifferentiated connective tissue syndrom, antiphospholipid syndrom, different forms of vasculitis (polyarteritis nodosa, allergic granulomatosis and angiitis, Wegner's granulomatosis, Kawasaki disease, hypersensitivity vasculitis, Henoch-Schoenlein purpura, Behcet's Syndrome, Takayasu arteritis, Giant cell arteritis, Thrombangiitis obliterans), lupus erythematosus, polymyalgia rheumatica, essentiell (mixed) cryoglobulinemia, Psoriasis vulgaris and psoriatic arthritis, diffus fasciitis with or without eosinophilia, polymyositis and other idiopathic inflammatory myopathies, relapsing panniculitis, relapsing polychondritis, lymphomatoid granulomatosis, erythema nodosum, ankylosing spondylitis, Reiter's syndrom, different forms of inflammatory dermatitis.

A more extensive list of disorders is given in WO-A-98/09985. For ease of reference, part of that list is now provided: unwanted immune reactions and inflammation including arthritis, including rheumatoid arthritis, inflammation associated with hypersensitivity, allergic reactions, asthma, systemic lupus erythematosus. collagen diseases and other autoimmune diseases, inflammation associated with atherosclerosis, arteriosclerosis, atherosclerotic heart disease, reperfusion injury, cardiac arrest, myocardial infarction, vascular inflammatory disorders, respiratory distress syndrome or other cardiopulmonary diseases, inflammation associated with peptic ulcer, ulcerative colitis and other diseases of the gastrointestinal tract, hepatic fibrosis, liver cirrhosis or other hepatic diseases, thyroiditis or other glandular diseases, glomerulonephritis or other renal and urologic diseases, otitis or other oto-rhino-laryngological diseases, dermatitis or other dermal diseases, periodontal diseases or other dental diseases, orchitis or epididimo-orchitis, infertility. orchidal trauma or other immune-related testicular diseases, placental dysfunction, placental insufficiency, habitual abortion, eclampsia, pre-eclampsia and other immune and/or inflammatory-related gynaecological diseases, posterior uveitis, intermediate uveitis, anterior uveitis, conjunctivitis, chorioretinitis, uveoretinitis, optic neuritis, intraocular inflammation, e.g. retinitis or cystoid macular oedema, sympathetic

ophthalmia, scleritis, retinitis pigmentosa, immune and inflammatory components of degenerative fundus disease, inflammatory components of ocular trauma, ocular inflammation caused by infection, proliferative vitreo-retinopathies, acute ischaemic optic neuropathy, excessive scarring, e.g. following glaucoma filtration operation, immune and/or inflammation reaction against ocular implants and other immune and inflammatory-related ophthalmic diseases, inflammation associated with autoimmune diseases or conditions or disorders where, both in the central nervous system (CNS) or in any other organ, immune and/or inflammation suppression would be beneficial, Parkinson's disease, complication and/or side effects from treatment of Parkinson's disease, AIDS-related dementia complex HIV-related encephalopathy, Devic's disease, Sydenham chorea, Alzheimer's disease and other degenerative diseases, conditions or disorders of the CNS, inflammatory components of stokes, post-polio syndrome, immune and inflammatory components of psychiatric disorders, myelitis, encephalitis, subacute sclerosing pan-encephalitis, encephalomyelitis, acute neuropathy, subacute neuropathy, chronic neuropathy, Guillain-Barre syndrome, Sydenham chora, myasthenia gravis. pseudo-tumour cerebri, Down's Syndrome, Huntington's disease, amyotrophic lateral sclerosis, inflammatory components of CNS compression or CNS trauma or infections of the CNS, inflammatory components of muscular atrophies and dystrophies, and immune and inflammatory related diseases, conditions or disorders of the central and peripheral nervous systems, post-traumatic inflammation, septic shock, infectious diseases, inflammatory complications or side effects of surgery or organ, inflammatory and/or immune complications and side effects of gene therapy, e.g. due to infection with a viral carrier, or inflammation associated with AIDS, to suppress or inhibit a humoral and/or cellular immune response, to treat or ameliorate monocyte or leukocyte proliferative diseases, e.g. leukaemia, by reducing the amount of monocytes or lymphocytes, for the prevention and/or treatment of graft rejection in cases of transplantation of natural or artificial cells, tissue and organs such as cornea, bone marrow, organs, lenses, pacemakers, natural or artificial skin tissue.

### E. Administration

Compounds capable of affecting a cADPR-mediated rise in  $\text{Ca}^{2+}$  levels in T cells for use in immunotherapy are typically formulated for administration to patients with a pharmaceutically acceptable carrier or diluent to produce a pharmaceutical composition. The formulation will depend upon the nature of the compound identified and the route of administration but typically they can be formulated for topical, parenteral, intramuscular, intravenous, intra-peritoneal, intranasal inhalation, lung inhalation, intradermal or intra-articular administration. The compound may be used in an injectable form. It may therefore be mixed with any vehicle which is pharmaceutically acceptable for an injectable formulation, preferably for a direct injection at the site to be treated, although it may be administered systemically.

The pharmaceutically acceptable carrier or diluent may be, for example, sterile isotonic saline solutions, or other isotonic solutions such as phosphate-buffered saline. The compounds of the present invention may be admixed with any suitable binder(s), lubricant(s), suspending agent(s), coating agent(s), solubilising agent(s). It is also preferred to formulate the compound in an orally active form.

In general, a therapeutically effective daily oral or intravenous dose of the compounds of the invention, including compounds of formula (1) and their salts, is likely to range from 0.01 to 50 mg/kg body weight of the subject to be treated, preferably 0.1 to 20 mg/kg. The compounds of the formula (I) and their salts may also be administered by intravenous infusion, at a dose which is likely to range from 0.001-10 mg/kg/hr.

Tablets or capsules of the compounds may be administered singly or two or more at a time, as appropriate. It is also possible to administer the compounds in sustained release formulations.

Typically, the physician will determine the actual dosage which will be most suitable for an individual patient and it will vary with the age, weight and response of the particular patient. The above dosages are exemplary of the average case. There can, of course, be

individual instances where higher or lower dosage ranges are merited, and such are within the scope of this invention.

Alternatively, the compounds of the invention, including the compounds of the general formula (1), can be administered by inhalation or in the form of a suppository or pessary, or they may be applied topically in the form of a lotion, solution, cream, ointment or dusting powder. An alternative means of transdermal administration is by use of a skin patch. For example, they can be incorporated into a cream consisting of an aqueous emulsion of polyethylene glycols or liquid paraffin. They can also be incorporated, at a concentration of between 1 and 10% by weight, into an ointment consisting of a white wax or white soft paraffin base together with such stabilisers and preservatives as may be required.

For some applications, preferably the compositions are administered orally in the form of tablets containing excipients such as starch or lactose, or in capsules or ovules either alone or in admixture with excipients, or in the form of elixirs, solutions or suspensions containing flavouring or colouring agents.

The compositions (as well as the compounds alone) can also be injected parenterally, for example intracavernosally, intravenously, intramuscularly or subcutaneously. In this case, the compositions will comprise a suitable carrier or diluent.

For parenteral administration, the compositions are best used in the form of a sterile aqueous solution which may contain other substances, for example enough salts or monosaccharides to make the solution isotonic with blood.

For buccal or sublingual administration the compositions may be administered in the form of tablets or lozenges which can be formulated in a conventional manner.

For oral, parenteral, buccal and sublingual administration to subjects (such as patients), the daily dosage level of the compounds of the present invention and their pharmaceutically acceptable salts and solvates may typically be from 10 to 500 mg (in single or divided doses). Thus, and by way of example, tablets or capsules may contain from 5 to 100 mg of

active compound for administration singly, or two or more at a time, as appropriate. As indicated above, the physician will determine the actual dosage which will be most suitable for an individual patient and it will vary with the age, weight and response of the particular patient. It is to be noted that whilst the above-mentioned dosages are exemplary of the average case there can, of course, be individual instances where higher or lower dosage ranges are merited and such dose ranges are within the scope of this invention.

T cells treated *ex vivo* are typically administered to the patient by intramuscular, intraperitoneal or intravenous injection, or by direct injection into the lymph nodes of the patient, preferably by direct injection into the lymph nodes. Typically from  $10^4$  to  $10^8$  treated cells, preferably from  $10^5$  to  $10^7$  cells, more preferably about  $10^6$  cells are administered to the patient.

The routes of administration and dosages described are intended only as a guide since a skilled practitioner will be able to determine readily the optimum route of administration and dosage for any particular patient depending on, for example, the age, weight and condition of the patient.

The present invention will now be described by way of examples which are intended to be illustrative only and non-limiting.

#### Brief Description of the Figures

Figure 1 - a, b, c - graphs of cADPR levels

Figure 2 - a, b, c, d, e, f - graphs of ratiometric  $\text{Ca}^{2+}$  measurements

Figure 3 - a, b, c, d - graphs of  $\text{Ca}^{2+}$  levels

Figure 4 - a, b, c - graphs



Detailed Description of the Figures**Figure 1 - Endogenous cADPR, ADP-ribosyl cyclase activation and  $[Ca^{2+}]_i$  in response to stimulation of the TCR/CD3 complex**

5 Jurkat T-lymphocytes ( $10^8/5$  ml intracellular buffer) were left unstimulated for at least 10 min at 37°C. Then cells were stimulated for the times indicated using anti-CD3 OKT3 (10 mg/ml, **a**). Extraction of cADPR by perchloric acid and subsequent neutralization as well as determination of cADPR was carried by a 2-step HPLC procedure using a PRP-X100 and a Hypersil BDS C18 column exactly as described in da Silva *et al.* (1998). Recovery and identity of endogenous cADPR were checked by internal standardisation using authentic cADPR (da Silva *et al.*, 1998). Data for unstimulated cells are from 24 experiments carried out during 1 year; time course analysis for OKT3 was carried out in 5 independent experiments (data presented as mean±SD). In **b**, cells were left unstimulated or exposed to either anti-CD3 OKT3 (10 µg/ml), thapsigargin (1 µM) or ionomycin 15 (200 nM) for 10 min, and endogenous cADPR was determined. Data are presented as mean±SD (n as indicated in the figure). **c**. To determine ADP-ribosyl cyclase activity  $NAD^+$  (100 µM) was incubated with cytosolic (S100) protein (2 mg/ml) at 37°C for 0, 1, 2, 3, 5 and 10 min. The reaction was stopped by perchloric acid (3 M) and cADPR was analysed by reverse phase HPLC as described in da Silva *et al.* (1998). S100 protein was 20 obtained from unstimulated cells (basal activity) or from cells stimulated by OKT3 (10 µg/ml) for 10 min; dephostatin (100 µM) was present during preparation of S100 proteins where indicated. Data are presented as mean±SEM from 4 independent S100 preparations (n as indicated in the Figure). Asterisks denote significant statistical differences to control values according to the Student's t-test ( $p > 0.92$ ).  $[Ca^{2+}]_i$  was determined in a suspension 25 of fura-2-loaded Jurkat T cells.

**Figure 2 - Inhibition of long-lasting  $Ca^{2+}$  signalling by 7-deaza-8-Br-cADPR**

$[Ca^{2+}]_i$  was measured in fura-2-loaded Jurkat T cells using a ratiometric single cell  $Ca^{2+}$  imaging system (Guse *et al.*, 1997). Cells were either untreated (**a**) or treated with 30 increasing concentrations of 7-deaza-8-Br-cADPR for 20 min (**b** 1 µM, **c** 10 µM, **d** 100 µM) prior to stimulation with anti-CD3 OKT3 (10 µg/ml). In **a** to **d** a typical experiment is displayed (cell number ranging from 20 to 35 cells for each condition). **e** shows  $[Ca^{2+}]_i$  at

1500 sec after OKT3 addition as combined data obtained in 5 independent experiments (108 to 203 individual cells investigated for each concentration of 7-deaza-8-Br-cADPR). Asterisks denote significant statistical differences to control values (without 7-deaza-8-Br-cADPR) according to the Student's t-test ( $p > 0.97$ ). f shows the effect of 7-deaza-8-Br-cADPR on  $\text{Ca}^{2+}$  signalling at 1500 sec stimulated by either OKT3 (10  $\mu\text{g/ml}$ ), thapsigargin (1  $\mu\text{M}$ ) or ionomycin (200 nM); data are presented as mean $\pm$ SD (3-4 independent experiments, 91 to 104 individual cells investigated; \*  $p > 0.95$ ).

**Figure 3 - Inhibition of  $\text{Ca}^{2+}$  signalling by microinjection of antagonists against Ins(1,4,5) $\text{P}_3$  and cADPR**

[ $\text{Ca}^{2+}$ ]<sub>i</sub> was measured in fura-2-loaded Jurkat T cells using a ratiometric single cell  $\text{Ca}^{2+}$  imaging system (Guse *et al.*, 1997). Single T cells were stimulated by OKT3 and either left untreated (a: n=10), or microinjected after the first  $\text{Ca}^{2+}$  spikes were observed with 100  $\mu\text{M}$  8-methoxy cADPR (b: n=11), 80  $\mu\text{M}$  Ins(1,4,6) $\text{P}_3$  (c: n=10) or a combination of both (d: n=12). Microinjection was carried out exactly as described in Guse *et al.* (1997). Combined data calculated as the relative percentage of the  $\text{Ca}^{2+}$  peak magnitude before and after microinjection of the respective compound(s) are displayed in (e). Data are presented as mean $\pm$ SEM. Asterisks denote statistical significances vs. OKT3 data ( $p > 0.95$ ).

**Figure 4 - Ryanodine receptor in T-lymphocytes: expression and cADPR effects**

Jurkat T cells were disrupted and 2 membrane fractions, P10 (10000 x g pellet) and P100 (100000 x g pellet), and the cytosolic fraction (S100) were prepared by ultracentrifugation.

a, Specific [ $^3\text{H}$ ]ryanodine binding to total Jurkat membranes was determined by a filtration assay in the absence or presence of unlabeled ryanodine. Kinetics of the specific binding of

200 nM [ $^3\text{H}$ ]ryanodine were investigated in the absence or presence of cADPR (10  $\mu\text{M}$ ; n=4-8).

b, The dose-dependency and specificity of the effect of cADPR on the velocity of specific [ $^3\text{H}$ ]ryanodine (200 nM) binding was assessed by a 30 min incubation of membranes at 37°C in the presence of different concentrations of cADPR, or for control in the presence of NAD (10  $\mu\text{M}$ ) or ATP (10  $\mu\text{M}$ ; n=4-8). Asterisks denote significant statistical differences to control values according to the Student's t-test (\*\*  $p > 0.90$ ; \*  $p > 0.95$ ).

c, The effect of cADPR (10  $\mu$ M) on specific binding of 200 nM [ $^3$ H]ryanodine to P10 membranes (30 min, 37 $^{\circ}$  C) was also measured in the presence of various compounds as indicated (n=3-8). Note that anti-RyR<sub>common</sub> mAb did not inhibit the effect of cADPR. Asterisks denote significant statistical differences to the value obtained with cADPR alone (second bar) according to the Student's t-test ( $p > 0.97$ ).

## EXAMPLES

### Materials and Methods

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*HPLC analysis of cADPR, ratiometric digital  $Ca^{2+}$  imaging, microinjection.*

These experiments were carried exactly as described by Guse *et al.* (1997) and da Silva *et al.* (1998).

15 

#### *Preparation of subcellular fractions*

Jurkat T cells ( $10^9$  cells) were disrupted in 5 ml 20 mM HEPES (pH 7.5), 110 mM NaCl and protease inhibitors (antipain 5  $\mu$ g/ml, leupeptin 5  $\mu$ g/ml, pepstatin 6.9 pg/ml. Pefablock SC 13.9  $\mu$ g/ml) in a Potter-Elvehjem homogenizer at 4 $^{\circ}$ C. Then, cell debris was removed at 500 x g for 10 min, and the supernatant was further centrifuged at 10000 x g (20 min, 4 $^{\circ}$ C) and the pellet (P10) harvested. The supernatant was again centrifuged at 100000 x g (120 min, 4 $^{\circ}$ C), and the pellet (P100) and the supernatant (S100) were harvested.

#### *Immunoprecipitation. SDS-PAGE and western blotting*

Anti-RyR<sub>common</sub> mAb was coupled to Protein G-Sepharose and incubated with solubilized P10 membranes in lysis buffer (25 mM HEPES pH 7.2, 150 mM NaCl, 0.25 % CHAPS (w/v), protease inhibitors as above) for 1.5 h at 4 $^{\circ}$ C under continuous shaking. Then, the Protein G-Sepharose beads were spun down (13000 x g, 1 min, 4 $^{\circ}$ C), the supernatant was discarded, and the immunoprecipitate rinsed with lysis buffer; this procedure was then repeated 3 times.

30

Protein was boiled at 95°C for 5 min and subjected to SDS-PAGE in a 6 % gel (3 % stacking gel) under reducing conditions. Proteins were subsequently transferred onto nitrocellulose sheets by tank blotting (18 h, 550 mA constant, 4°C). The nitrocellulose sheets were washed by a complex procedure and the blots were developed using the ECL-kit (Amersham) according to the manufacturer's instructions.

#### *Binding of [<sup>3</sup>H]ryanodine to P10 membranes*

Binding of [<sup>3</sup>H]ryanodine was measured in 20 mM HEPES, pH 7.4, 0.75 M KCl, CaCl<sub>2</sub> 1.1 mM, EGTA 1.0 mM ([Ca<sup>2+</sup>]<sub>free</sub> ≈ 100 μM) using 200 μg protein in a 50 ml volume at 37°C and continuous shaking. Unspecific binding was determined in the presence of 1000-fold excess of unlabeled ryanodine. Separation of bound from free radioactivity was achieved by rapid filtration on glass fiber filters (Whatman type GF/B). Then, the filters were rinsed rapidly 4 times with 3 ml ice-cold buffer containing 10 mM HEPES, pH 7.4, 0.75 M KCl, CaCl<sub>2</sub> 1.1 mM, EGTA 1.0 mM ([Ca<sup>2+</sup>]<sub>free</sub> ≈ 100 μM), and subjected to liquid scintillation counting. Analysis of binding isotherms (at 37°C) resulted in K<sub>d</sub> = 43±18 nM (n=3) and a maximal number of specific binding sites of 66±11 fmol/mg protein (n=3).

#### *RT-PCR*

To amplify RyR cDNA sequences, PCR was initially performed with cDNA from unstimulated Jurkat T cells and oligonucleotide primers corresponding to a highly conserved sequence from the C-terminal region of all known RyR isoforms. Thus, an antisense primer was designed that was homologous to all 3 human RyR sequences (5' ACATCTTCCAGACATAAG 3') whereas redundant primers were used as sense oligos (5' AC(T/C)CACAATGG(C/G)AAACAG 3'). In addition, specific primers for type 3 RyR were used (sense: 5' CGACATGATGACGTGTTACC 3', antisense: 5' CTCGTACTTGT TCCTGCTGG 3').

#### **Example 1 - Stimulation of T cell Ca<sup>2+</sup> signalling via the TCR/CD3 complex leads to a sustained increase in intracellular cADPR.**

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Cyclic ADP-ribose (cADPR) has been discovered as a potent Ca<sup>2+</sup>-mobilizing compound in sea urchin eggs (Lee, 1997 and Galione *et al.*, 1991). In the past decade, it has been

shown that cADPR is also active in plants and in higher eukaryotes including a variety of mammalian tissues or cell types, such as cardiac and smooth muscle, pancreatic and parotid acinar cells, hepatocytes, PC12 cells GH<sub>4</sub>C<sub>1</sub> cells, and T-lymphocytes (reviewed in Lee *et al.*, 1997).

5

We have recently demonstrated in human Jurkat T-lymphocytes (i) that cADPR specifically releases Ca<sup>2+</sup> from a D-*myo*-inositol 1,4,5-trisphosphate [Ins(1,4,5)P<sub>3</sub>]-insensitive Ca<sup>2+</sup> pool of permeabilized cells (Guse *et al.*, 1995 and Guse *et al.*, 1996), (ii) that cADPR stimulates sustained Ca<sup>2+</sup> signalling in response to microinjection into intact  
10 cells (Guse *et al.*, 1997), and (iii) that cADPR is an endogenous nucleotide (da Silva *et al.*, 1998).

Despite these findings it remained unclear (i) whether cADPR would act as a second messenger in response to stimulation of the TCR/CD3-complex, and (ii) in which process  
15 of Ca<sup>2+</sup> signalling cADPR would exactly be involved. Previous studies have shown that activation of the TCR/CD3-complex involves the elevation of the free cytosolic Ca<sup>2+</sup> concentration ([Ca<sup>2+</sup>]<sub>i</sub>) by at least two mechanisms, a rapid elevation caused by Ca<sup>2+</sup> release from intracellular stores mediated by Ins(1,4,5)P<sub>3</sub> and a prolonged elevation that is completely dependent on the influx of extracellular calcium (reviewed in Guse, 1998).  
20 Ins(1,4,5)P<sub>3</sub> appears to play an essential role in Ca<sup>2+</sup> signalling stimulated *via* the TCR/CD3-complex. since expression of an anti-sense construct directed against the type 1 Ins(1,4,5)P<sub>3</sub>-receptor in Jurkat T cells resulted in complete abolishment of CD3-mediated Ca<sup>2+</sup> signalling (Jayaraman *et al.*, 1995).

25 The exact mechanism of Ca<sup>2+</sup> entry in T cells is still unknown. To find out whether cADPR would play a second messenger role in T-lymphocytes a recently developed selective two step HPLC method for quantification of endogenous cADPR was used. The agonistic anti-CD3 antibody OKT3 induced a slowly rising, but sustained increase in intracellular cADPR reaching its highest level 30 min after stimulation, a level that was  
30 still maintained after 60 min (Figure 1a). In addition, we have reported that the endogenous inorganic phosphate concentration (P<sub>i</sub>) modulates cADPR effects by increased

loading of cADPR-sensitive  $\text{Ca}^{2+}$  stores (Guse *et al.*, 1995). Since  $\text{P}_i$  increased in response to OKT3 this may additionally contribute to the action of cADPR.

In contrast to OKT3, stimulation of  $\text{Ca}^{2+}$  signalling by artificial store depletion using thapsigargin did not result in elevation of endogenous cADPR (Figure 1b). Likewise, elevation of  $[\text{Ca}^{2+}]_i$  by a moderate concentration of ionomycin which stimulated a  $\text{Ca}^{2+}$  signal comparable to OKT3, did not increase the level of endogenous cADPR (Figure 1b) indicating that the ADP-ribosyl cyclase involved in TCR/CD3 signalling is not unspecifically stimulated by increased  $[\text{Ca}^{2+}]_i$ . Stimulation of T cells by OKT3 in the absence of extracellular  $\text{Ca}^{2+}$  resulted in a comparable time course of cADPR as shown in Figure 1a (data not shown).

As a potential link between TCR/CD3-stimulation and increased cADPR concentration, a novel ADP-ribosyl cyclase was detected at low basal activity in the cytosolic fraction of Jurkat cells (Figure 1c). In contrast to known ADP-ribosyl cyclases, like the soluble one from *Aplysia californica* (Hellmich and Strumwasser, 1991) or the plasma membrane bound ectoenzyme CD38 (Howard *et al.*, 1993), the soluble ADP-ribosyl cyclase from Jurkat T cells did not use nicotinamide guanine dinucleotide as substrate (data not shown). Most importantly, the initial reaction velocity of this enzyme was increased significantly (about 2.8-fold) in T cells stimulated by OKT3 (Figure 1c). Moreover, when the cells were stimulated by OKT3 and, subsequently, the cytosolic fraction was prepared in the presence of the Tyr-phosphatase inhibitor dephostatin (Imoto *et al.*, 1993), an about 5-fold increase of cyclase activity was observed (Figure 1c) indicating activation by Tyr-phosphorylation of the soluble cyclase.

#### **Example 2 - The cADPR antagonist 7-deaza-8-Br-cADPR inhibits TCR/CD3-mediated $\text{Ca}^{2+}$ entry.**

To finally prove a causal relationship between the TCR/CD3-mediated elevation of cADPR and  $[\text{Ca}^{2+}]_i$ , the following approaches were used. First, Jurkat T cells were preincubated with the novel membrane-permeant cADPR-antagonist 7-deaza-8-Br-cADPR and subsequently  $\text{Ca}^{2+}$  signalling stimulated by OKT3 was measured using digital ratiometric

Ca<sup>2+</sup> imaging (Figure 2). On the single cell level OKT3 stimulated rapid and sustained Ca<sup>2+</sup> signalling (Figure 2a). Individual cells responded in different ways: oscillations, longlasting elevations, single spikes; however, the majority of cells showed Ca<sup>2+</sup> signalling for more than 20 min after stimulation (Figure 2a). Such longlasting responses were never  
5 observed in the absence of extracellular Ca<sup>2+</sup> (data not shown), and therefore mainly reflect Ca<sup>2+</sup> entry.

Preincubation with 1 µM 7-deaza-8-Br-cADPR did not significantly change the pattern of Ca<sup>2+</sup> signalling (Figure 2b). However, at higher concentrations (10 and 100 µM) 7-deaza-  
10 8-Br-cADPR induced a profound inhibitory effect on the long-lasting Ca<sup>2+</sup> entry (Figure 2c,d). Statistical analysis revealed a highly significant reduction of Ca<sup>2+</sup> signalling at 1500 sec after stimulation, suggesting an essential role of cADPR in the important process of Ca<sup>2+</sup> entry (Figure 2e). In addition 7-deaza-8-Br-cADPR dose-dependently increased the delay between OKT3 addition and the onset of the Ca<sup>2+</sup> signal (Figure 2c,d) indicating that  
15 cADPR is already involved in the early period of Ca<sup>2+</sup> signalling. An non-specific effect of 7-deaza-8-Br-cADPR on Ins(1,4,5)P<sub>3</sub>-induced Ca<sup>2+</sup> release is rather unlikely because the closely related derivative 8-Br-cADPR has been shown up to 100 µM to be without any inhibitory effect on Ins(1,4,5)P<sub>3</sub>-induced Ca<sup>2+</sup> release in T cells. Importantly, 7-deaza-8-Br-cADPR did not inhibit the sustained Ca<sup>2+</sup> signalling stimulated by either store-depletion  
20 using thapsigargin nor by unspecific elevation of [Ca<sup>2+</sup>]<sub>i</sub> by ionomycin (Figure 2f).

Figure 2c and d also demonstrate that the membrane-permeant antagonist 7-deaza-8-Br-cADPR did not influence the first phase of Ca<sup>2+</sup> signalling, which is thought to be driven mainly by Ins(1,4,5)P<sub>3</sub>. Indeed, the novel membrane-permeant Ins(1,4,5)P<sub>3</sub> antagonist  
25 xestospongine C, which has been shown to potently block Ins(1,4,5)P<sub>3</sub>-mediated Ca<sup>2+</sup> release, but up to an extracellular concentration of 20 µM to be without effect on RyR-mediated Ca<sup>2+</sup> release, inhibited TCR/CD3-mediated Ca<sup>2+</sup> signalling after preincubation of the cells for 20 min at 2 µM (data not shown). Our results, together with the data from the type 1 Ins(1,4,5)P<sub>3</sub>-receptor knock-out T cell line, indicate (i) that an initial Ins(1,4,5)P<sub>3</sub>-  
30 mediated Ca<sup>2+</sup> signalling event is necessary, but not sufficient for sustained Ca<sup>2+</sup> signalling, (ii) that cADPR is essential for the sustained second phase, and (iii) that cADPR is also involved in determining the time of onset of Ca<sup>2+</sup> signals after TCR/CD3 stimulation.

**Example 3 - cADPR antagonists but not IP<sub>3</sub> antagonists inhibit the second phase, sustained rise in Ca<sup>2+</sup> levels in response to TCR/CD3 stimulation.**

5 The membrane-permeant antagonists 7-deaza-8-Br-cADPR and xestospongin C are powerful tools, but to achieve a sufficiently high intracellular effective concentration, a substantial preincubation period must be employed. To find out whether either Ins(1,4,5)P<sub>3</sub> or cADPR or both play an essential role also at a later time point after TCR/CD3 stimulation, we stimulated the cells by OKT3, and, after development of Ca<sup>2+</sup> signalling, microinjected a specific antagonist, e.g. inositol 1,4,6-trisphosphorothioate (Ins(1,4,6)PS<sub>3</sub>), or 8-methoxy-cADPR, or a combination of both (Figure 3). Following the development of Ca<sup>2+</sup> signalling stimulated by OKT3, microinjection of 8-methoxy-cADPR, a novel cADPR antagonist of similar potency as 8-NH<sub>2</sub>-cADPR, significantly decreased the magnitude of further Ca<sup>2+</sup> signals (Figure 3a, b, e), whereas microinjection of Ins(1,4,6)P S<sub>3</sub> did not have a significant effect (Figure 3a, c, e). Combined microinjection of 8-methoxy-cADPR and Ins(1,4,6)P S<sub>3</sub> resulted in a somewhat more pronounced inhibition as compared to 8-methoxy-cADPR alone (Figure 3e). These data confirm the concept of both an initial Ca<sup>2+</sup> signalling phase for which Ins(1,4,5)P<sub>3</sub> is essential, and a sustained phase driven mainly by cADPR.

**Example 4 - Functional ryanodine receptors are expressed in Jurkat T cells and their activity modulated by cADPR.**

Ca<sup>2+</sup> release by cADPR has been proposed to proceed *via* ryanodine receptors (RyR) (Galione *et al.*, 1991). Recently, we obtained pharmacological evidence that cADPR acts *via* RyR in T cells. Ca<sup>2+</sup> release stimulated by cADPR in permeabilised T cells was effectively inhibited by (i) ruthenium red and (ii) high Mg<sup>2+</sup> concentrations. Both ruthenium red and high Mg<sup>2+</sup> concentrations are proven as inhibitors of activation of RyR. In contrast, there was no inhibition of Ins(1,4,5)P<sub>3</sub>-induced Ca<sup>2+</sup> release by these treatments indicating a specific antagonistic effect on RyR. Despite these results and the fact that the Ca<sup>2+</sup> mobilising effects of cADPR in T cells have been reported independently by different groups, the expression of RyR in T cells has been a matter of debate. RyRs have been



detected in T cells by binding studies and western blot and by northern blot analysis. Sequencing of a cDNA clone obtained from Jurkat T cell poly(A)<sup>+</sup> RNA showed 95 % identity on the amino acid level to rabbit brain RyR in the C-terminal region. In contrast, transcripts for RyRs have not been detected in another Jurkat clone using RT-PCR. We report here that RyR is clearly expressed in the Jurkat T cell line employed in our laboratory as assessed by western blot and immunoprecipitation experiments using an anti-RyR<sub>common</sub> mAb. A band of about 500 kDa was detected specifically in P10 membranes prepared from Jurkat cells, but not in the cytosolic fraction (data not shown). Furthermore, immunoprecipitation of solubilised P10 membranes with anti-RyR<sub>common</sub> mAb resulted in profound enrichment of the RyR (data not shown). These data were confirmed by RT-PCR of poly(A)<sup>+</sup> RNA from Jurkat T cells. Using redundant primers for all RyR subtypes, a PCR product of the expected size was obtained; the nucleotide sequence from the amplified product was identical with a sequence from type 3 RyR. A sequence identical to a type 3 RyR sequence was also obtained when specific primers for the type 3 RyR were used (data not shown).

In addition, specific binding of [<sup>3</sup>H]ryanodine to Jurkat membranes was observed. Importantly, there was a significant stimulatory effect of cADPR on the apparent association velocity of [<sup>3</sup>H]ryanodine, but not on the capacity of [<sup>3</sup>H]ryanodine binding to Jurkat membranes (Figure 4a). These findings indicate a direct modulatory effect on channel opening by cADPR, since [<sup>3</sup>H]ryanodine is suggested to bind the RyR in the open conformation. A similar kinetic effect of cADPR has been reported for Ca<sup>2+</sup> release from cardiac and rat brain microsomes. The stimulatory effect of cADPR on the binding velocity of ryanodine was dose-dependent (Figure 4b) and specific because (i) it was not observed with ATP or NAD (Figure 4b), and (ii) it was reversed by either high Mg<sup>2+</sup> concentration, ruthenium red, 8-methoxy cADPR or 7-deaza-8-Br-cADPR (Figure 4c). Importantly, both high Mg<sup>2+</sup> concentration and ruthenium red decreased [<sup>3</sup>H]ryanodine binding below control levels whereas the cADPR-antagonists only reversed the stimulatory effect of cADPR (Figure 4c).

**Example 5 - Sustained  $\text{Ca}^{2+}$  signalling via a cADPR pathway is necessary for the activation of peripheral T-lymphocytes**

Sustained  $\text{Ca}^{2+}$  signalling is necessary for activation of peripheral T-lymphocytes. The experiments described so far point towards an important role of cADPR in this process. To confirm this, peripheral T cells were activated by solid-phase bound anti-CD3 mAb in the presence of increasing concentrations of 7-deaza-8-Br-cADPR. Proliferation was inhibited partially by 10 mM, and completely by 100 mM 7-deaza-8-Br-cADPR (Table 1). Similarly, the expression of the T cell activation markers CD25 and HLA-DR was markedly suppressed by increasing concentrations of 7-deaza-8-Br-cADPR (Table 1). Most importantly, after a 5 day exposure of the cells to 100 mM 7-deaza-8-Br-cADPR more than 70 % of the cells still were detected in the lymphocyte gate; of these > 95 % were negative for propidium iodine staining, indicating almost no non-specific cytotoxic effect of the antagonist.

Table 1 - Highly purified human peripheral blood T cells ( $5 \times 10^4$ ) were pulsed with the indicated inhibitors for 30 min at  $37^\circ\text{C}$  in the absence of serum, and then transferred to flat bottom 96 well plates coated with anti-CD3 mAb and cultured in RPMI 1640 containing 10 % NHS. The cells were incubated for 96 h in the presence of the indicated inhibitors. [ $^3\text{H}$ ]Thymidine was added for the last 16 h of culture. Results are given as mean cpm  $\pm$ SEM for quadruplicate determinations of one of three independent experiments with similar results (3 different healthy donors). Expression of CD25 and HLA-DR was determined by staining with directly labelled mAbs to CD25 and HLA-DR and analysed by flow cytometry. Histograms were gated for viable lymphocytes. Cyclosporin A (CsA) was added for comparison as an established inhibitor of T cell activation.

**Table 1**

Addition	[ $^3\text{H}$ ]thymidine incorporation [cpm $\pm$ SEM]	expression of CD25 (% pos. cells)	expression of HLA-DR (% pos. cells)
Control	148494 $\pm$ 17414	24.5	6.0

7-deaza-8-Br-cADPR (1 $\mu$ M)	156730 $\pm$ 13335	16.1	7.6
7-deaza-8-Br-cADPR (10 $\mu$ M)	94124 $\pm$ 9020	14.1	5.3
7-deaza-8-Br-cADPR (100 $\mu$ M)	42 $\pm$ 8	9.8	2.7
CsA(50 ng/ml)	41807 $\pm$ 16424	12.7	4.9

### Summary

In conclusion, we propose that cADPR is formed as an essential second messenger in response to stimulation of the TCR/CD3-complex and mediates the second, sustained phase of  $\text{Ca}^{2+}$  signalling *via* ryanodine receptor/ $\text{Ca}^{2+}$  channels in T cells. Although we have delineated the signalling pathway from the TCR/CD3-complex in the plasma membrane up to the RyR, the exact mechanism by which cADPR regulates  $\text{Ca}^{2+}$  entry is not yet clear. However, since cADPR by releasing  $\text{Ca}^{2+}$  from its target store also mediated  $\text{Ca}^{2+}$  pool depletion, it might act in a similar way as suggested for  $\text{Ins}(1,4,5)\text{P}_3$  in the classical capacitative model.

Finally, our data indicate that modulation of the cADPR signalling pathway in T cells may have important therapeutic implications. Starting from the membrane permeant antagonist 7-deaza-8-Br-cADPR novel pharmaceuticals may be developed that can be used to modulate undesirable immune reactions, e.g. immune hyperreactivity, autoimmune diseases and graft rejection.

### Example 6 - Treatment of antigen-induced arthritis (AIA) in mice by antagonists of cyclic ADP- ribose (cADPR)

It has now been shown in the above examples that antagonists of cADPR specifically inhibited activation of human T-lymphocytes as measured by inhibition of intracellular  $\text{Ca}^{2+}$ -signalling, expression of activation antigens and proliferation of the cells. T-lymphocytes are involved in the genesis of various autoimmune diseases, e.g. rheumatoid

arthritis. An established animal model for rheumatoid arthritis is the antigen-induced arthritis (AIA) in mice. We have therefore examined the effects of a cADPR antagonist, 7-deaza-8-Br-cADPR, on AIA in mice.

### 5 *Experimental procedures*

Female C57BL/6 mice were immunised at day -21 and day -14 with methylated bovine serum albumin (mBSA) in complete Freund's adjuvant. The experimental arthritis was induced at day 0 by injection of mBSA into the right knee joint.

10 Treatment from day 0 (6h after injection of mBSA) to day 21 was carried out by daily intraperitoneal injection of 100 µl of either vehicle: 0.9 % NaCl solution (n=8), 7-deaza-8-Br-cADPR 0.2 µmol/kg (n=5) and as positive control: Lipotalon (Dexamethasonpalmitat) 500 µg/kg (n=9).

15 During the treatment period the following parameters were investigated:

*swelling of right knee joint:* the swelling was determined at days 3, 5, 7, 14 and 21.

Swelling was calculated as relative swelling compared to the thickness of the joint at day 0.

20 *body weight:* weight was determined at days 3, 5, 7, 14 and 21. Body weight was calculated as relative body weight as compared to the body weight at day 0.

### Results

25 The specific cADPR antagonist 7-deaza-8-Br-cADPR was applied at the very low dose of 0.2 µmol/kg. A reduction in joint swelling was observed at day 3, 5, 7 and 14 as compared to the vehicle alone.

30 These data, as a proof of principle, indicate that autoimmune diseases can be successfully treated by antagonists of cADPR.

The specific cADPR antagonist 7-deaza-8-Br-cADPR did not significantly change the body weight during the course of treatment. In marked contrast, the anti-inflammatory drug dexamethasone (lipotalon) induced a significant reduction in body weight.

- 5 These data suggest that therapy of autoimmune diseases by antagonists of cADPR does not have a general toxic effect on the animals since during the course of therapy (21 days), 7-deaza-8-Br-cADPR did not induce visible toxic effects.

Conclusion: The new data provide the proof of principle for the beneficial effects of  
10 antagonists of cADPR in the therapy of autoimmune diseases.

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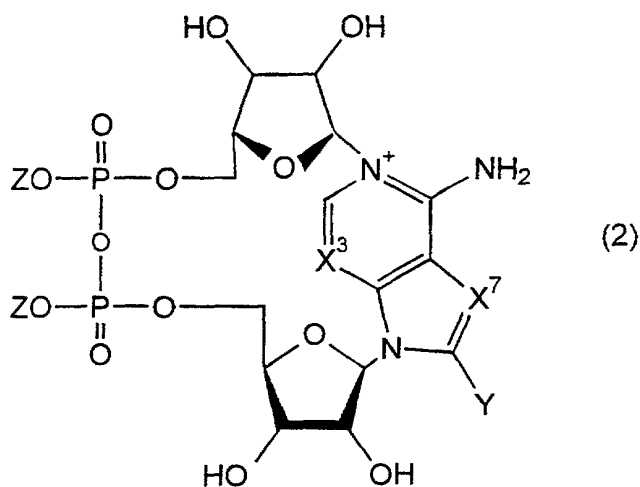
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CLAIMS

1. Use of a compound capable of antagonising a sustained cADPR-mediated rise in intracellular  $\text{Ca}^{2+}$  levels in a T cell, said rise being in response to stimulation of the T cell receptor/CD3 complex of the T cell, in the manufacture of a medicament for use in modulating T cell activity.
2. Use according to claim 1 wherein the compound modulates the binding of cADPR to a ryanodine receptor/ $\text{Ca}^{2+}$  channel.
3. Use according to claim 1 or claim 2 wherein the compound is a cADPR analogue.
4. Use according to claim 3 wherein the compound comprises an adenine component to which is individually linked two ribose moieties or a derivative(s) thereof, which ribose moieties are joined *via* a pyrophosphate bridging group.
5. Use according to claim 3 wherein the compound has the formula (2):



wherein:

X<sup>3</sup> is independently selected from CR<sup>1</sup> and N;

X<sup>7</sup> is independently selected from CR<sup>2</sup> and N;

Y is halo, C<sub>1</sub> to C<sub>20</sub> hydrocarbyl, N(R<sup>3</sup>)(R<sup>4</sup>), OR<sup>5</sup>, SR<sup>6</sup> nitro and carboxyl;

each of R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup> and R<sup>6</sup> is independently selected from H and C<sub>1</sub> to C<sub>20</sub> hydrocarbyl; and

Z is independently selected selected from H and a caging group;  
or a bio-isostere; or a pharmaceutically acceptable salt thereof.

6. Use of a compound as defined in any one of claims 1 to 5 in the manufacture of a medicament for use in modulating the immune response of a mammal.

7. Use of a compound as defined in any one of claims 1 to 5 in the manufacture of a medicament for use in treating an autoimmune disease or graft rejection.

8. Use according to claim 7 wherein the autoimmune disease is selected from thyroiditis, insulinitis, multiple sclerosis, iridocyclitis, uveitis, orchitis, hepatitis, Addison's disease, myasthenia gravis, rheumatoid arthritis and lupus erythematosus.

9. Use of a compound as defined in any one of claims 1 to 5 in the manufacture of a medicament for use in treating or preventing an immune disorder in a human or animal.

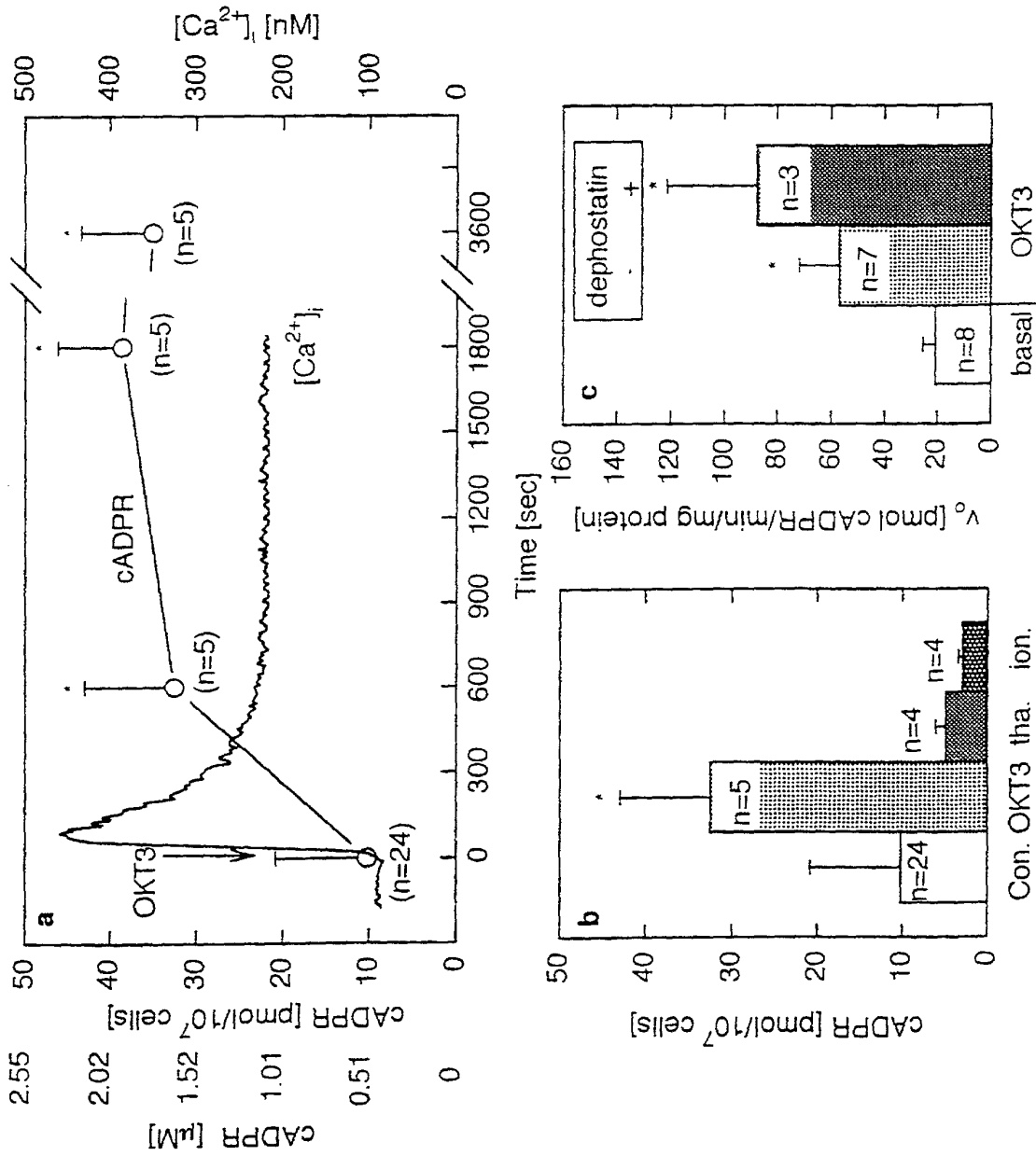
10. A method of treating a human or animal patient suffering from an immune disorder which method comprises administering to the patient an effective amount of a compound as defined in any one of claims 1 to 5.

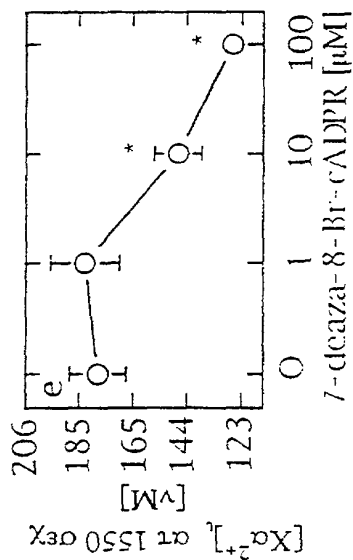
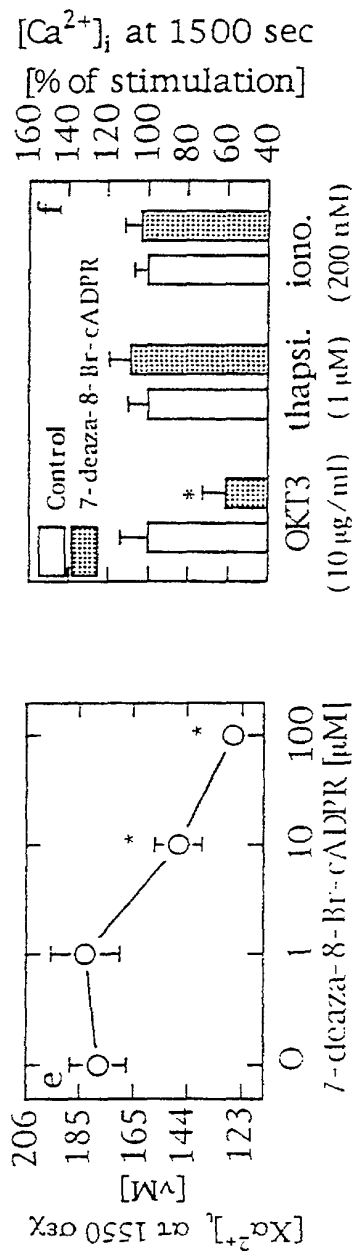
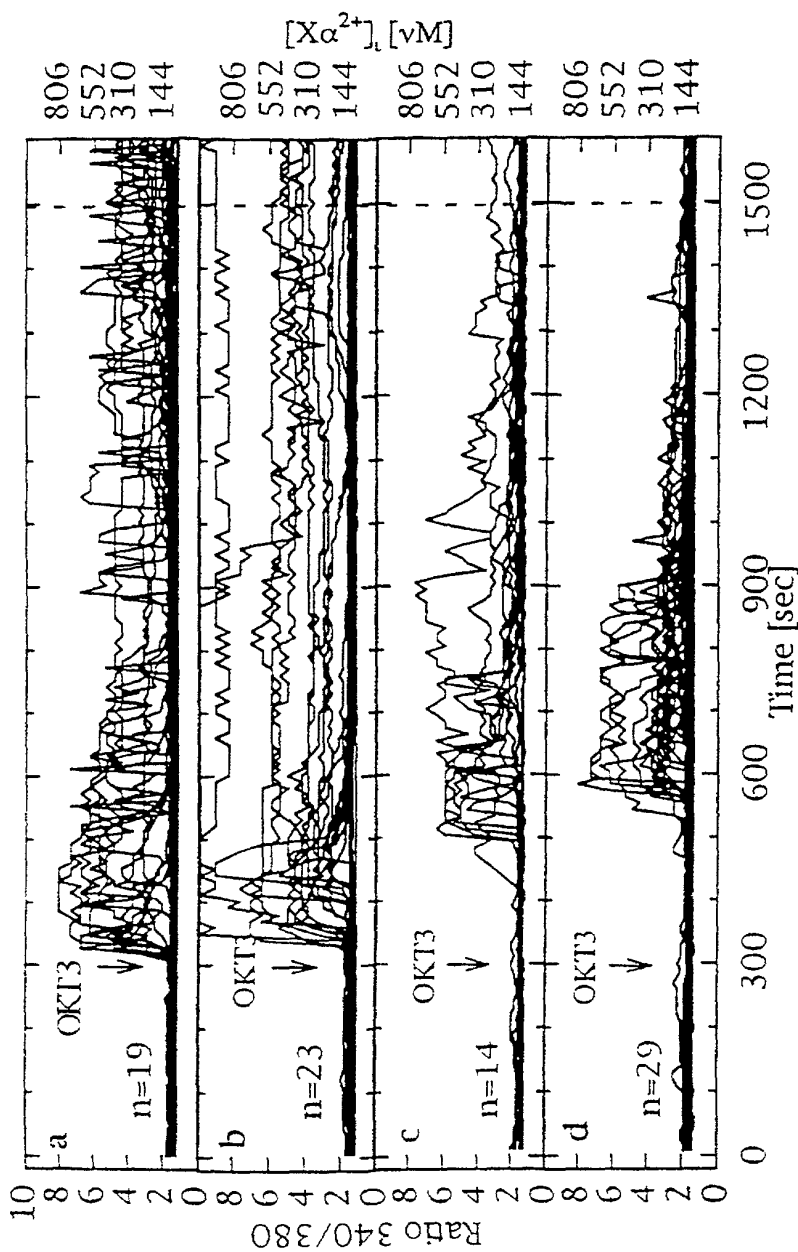
11. A method for identifying a substance capable of modulating a sustained rise in Ca<sup>2+</sup> entry *via* a cADPR-mediated pathway which method comprises:

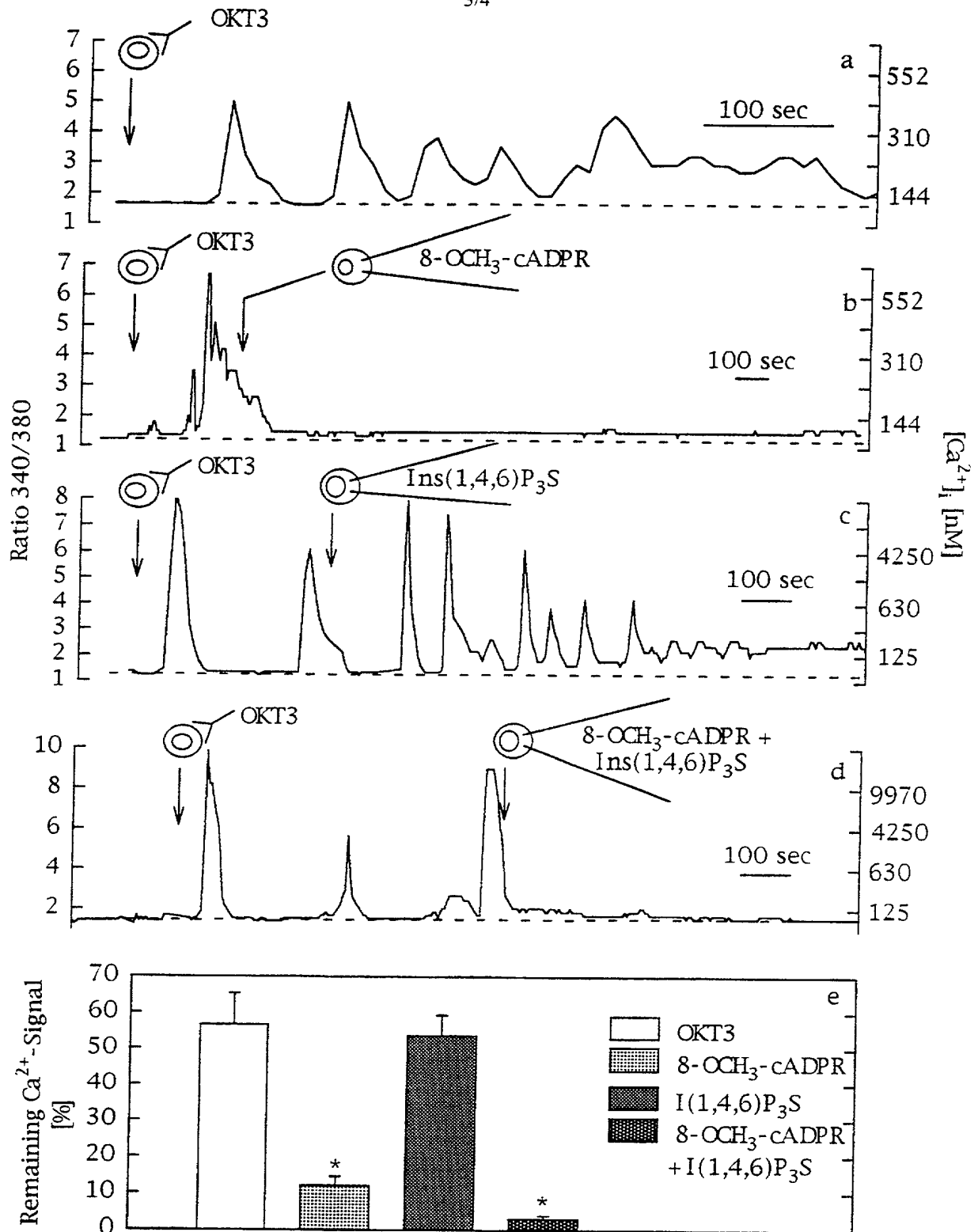
- (i) contacting an ADP-ribosyl cyclase or a homologue, variant or derivative thereof, with a substance to be tested under conditions that would permit the synthesis of cADPR in the absence of the substance; and
- (ii) determining whether the substance affects cADPR synthesis.

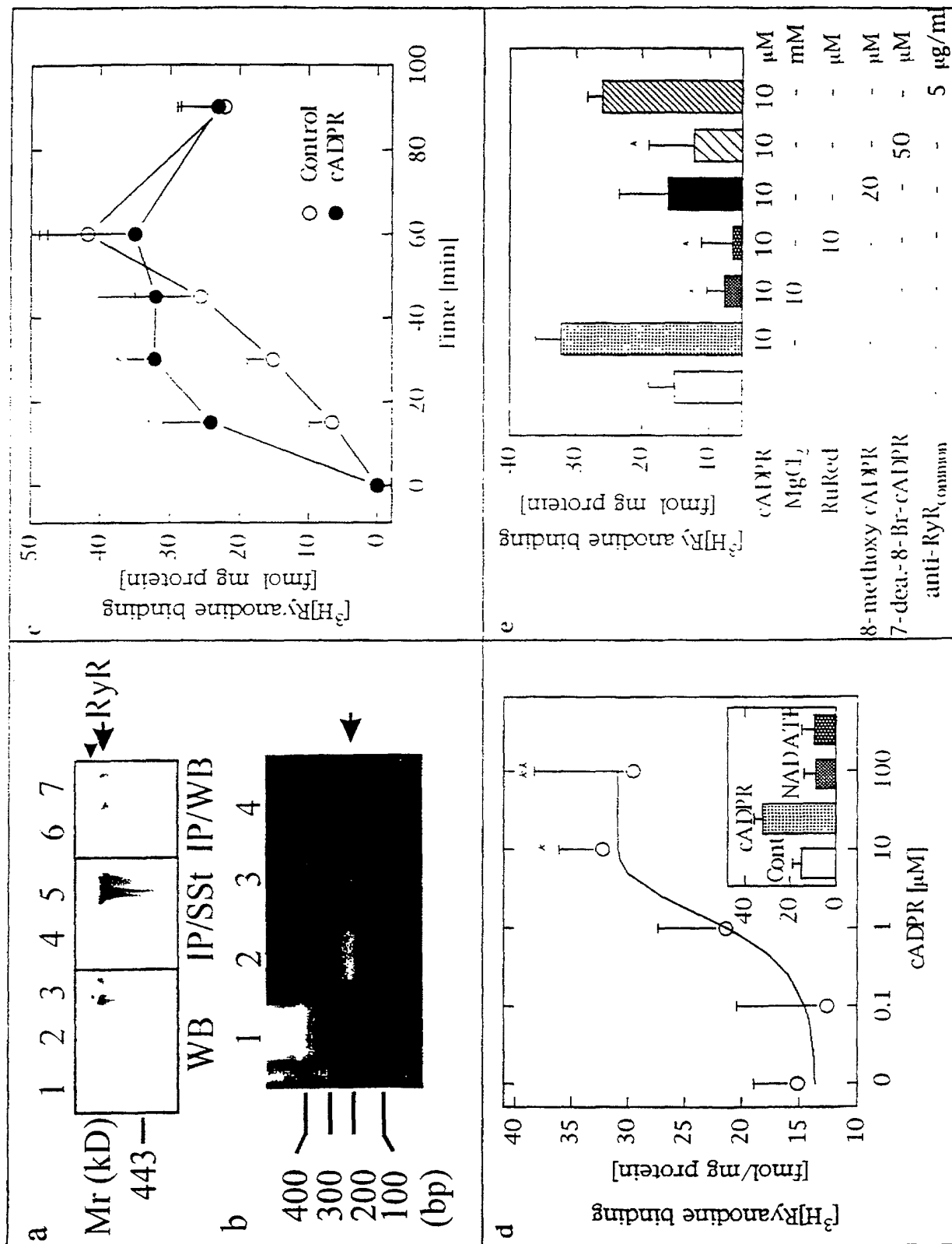


12. A method according to claim 11 wherein the substance inhibits cADPR synthesis.
13. A method for identifying a substance capable of modulating a sustained rise in  $\text{Ca}^{2+}$  entry *via* a cADPR-mediated pathway which method comprises:
- (i) contacting a T cell, which has been stimulated *via* its T cell receptor, with a candidate substance under conditions that would permit a sustained rise in intracellular  $\text{Ca}^{2+}$  levels in the absence of the substance; and
  - (ii) determining whether the substance inhibits a sustained rise in intracellular  $\text{Ca}^{2+}$  levels.
14. A compound identified by the method of claim 11, 12 or 13 for use in treating or preventing an immune disorder.
15. A compound identified by the method of claim 11, 12 or 13.
16. A process comprising the steps of:
- (a) performing the method according to claim 11, 12 or 13;
  - (b) preparing a quantity of those one or more substances identified as being capable of modulating a sustained rise in  $\text{Ca}^{2+}$  entry *via* a cADPR-mediated pathway.
17. A process comprising the steps of:
- (a) performing the method according to claim 11, 12 or 13; and
  - (b) preparing pharmaceutical composition comprising one or more substances identified as being capable of modulating a sustained rise in  $\text{Ca}^{2+}$  entry *via* a cADPR-mediated pathway.
18. A process comprising the steps of:
- (a) performing the method according to claim 11, 12 or 13; and
  - (b) modifying one or more of the substances identified as being capable of modulating a sustained rise in  $\text{Ca}^{2+}$  entry *via* a cADPR-mediated pathway to cause a different effect on T cell activity.









## DECLARATION AND POWER OF ATTORNEY

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As below-named inventors, we hereby declare that:

Our residences, post office addresses, and citizenships are as stated below next to our names.

We believe that we are the original, first and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled "Cyclic Adenoside Diphosphate Ribose Analogues for Modulating T Cell Activity, the specification of which was sent to the U.S.P.T.O. as U.S. national phase entry of PCT/GB99/04295 filed internationally on 17 December 1999 on 15 June 2001.

We hereby state that we have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above. To the best of our knowledge, information, and belief the facts stated therein are true.

We acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

We hereby claim foreign priority benefits under Title 35, United States Code §119 of the following foreign applications:

GB 9828071.2, filed 18 December 1998, and  
PCT/GB99/04295, filed 17 December 1999.

We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

We hereby appoint Mary M. Krinsky, Registration No. 32,423, 79 Trumbull Street, New Haven, CT 06511-3708 (203-773-9544), with full power of substitution, association and revocation, as attorney to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith. Please direct all telephone calls and correspondence to Mary M. Krinsky at the above address and telephone number.

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